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EFFECTS OF PURITY LEVEL ON THE MECHANICAL PROPERTIES OF 7000-SERIES ALUMINUMS

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Materials Integrity Branch
Systems Support Division

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The effect of purity level on the mechanical properties of high strength aluminum alloys was studied. Seven extrusions, representing three alloys, were tested for their mechanical properties. Three extrusions were 7049-T73511, one was 7050-T73511, and the remaining were 7075-T73511. The 7049 and 7075 extrusions were manufactured in three purity levels, indexed to iron and silicon. When going from high purity to low purity, the following observations were made; the tensile strength dropped slightly, the fracture toughness fell dramatically

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and fatigue and fatigue crack growth rate properties were not affected in a systematic manner. Stress corrosion cracking tests showed there does not appear to be a corrosion problem for any of the materials or purity levels.

PREFACE

This program represents the combined efforts of two organizations and a number of individuals. Martin Marietta Aluminum provided the materials to the Materials Laboratory who, in turn, performed the testing which is reported herein. Mr. Robert Giesendorfer, formerly of the Materials Laboratory and presently at Battelle Northwest, was responsible for designing the test program, supervising the testing, data reduction, chemical analysis and metallography, and compiling much of the data. Mr. Neal Ontko, of the Materials Laboratory, was responsible for much of the fatigue crack growth rate testing and data reduction. The author did nothing more than take the data and present them in the format contained herein.

This work was performed under Project No. 2418, "Metallic Structural Materials," Task No. 241807, "Systems Support for Metallic Materials Applications."

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SECTION I

INTRODUCTION

Aluminum alloys comprise a major portion of the structural load carrying members of modern aircraft. Knowledge of the mechanical properties of these alloys is important for an accurate design that will provide safe long-term operation and low maintenance costs of the structures. In recent years the aluminum industry developed new alloys and processes which possess improved mechanical properties. Some of these alloys were derivations of older alloys with tighter controls on impurity levels which translates to higher costs because of more stringent processing standards. This prompted the question of what effect impurity levels have on mechanical properties of both the older and newer alloys.

The two groups of aluminum alloys that comprise most of the aerospace structural alloys are the 2000- and 7000-series. In both series new alloys have been developed primarily by controlling the impurity levels, e.g., 2124 as a derivative of 2024 and 7175 as a derivative of 7075. Within the 7000-series a large number of such alloys have been produced by lowering the allowable Si and Fe content. Alloy 7149 was registered by Kaiser as a "cleaned up" 7049 and 7175 and 7475 by Alcoa are variations of 7075.

In order to assess the influence impurity elements Si and Fe have on mechanical properties, an agreement was entered into with Martin Marietta Aluminum who produced extrusions of 7000-series aluminums with varying impurity (purity) levels. Seven extrusions were produced and heat treated to the T73511 condition. Three of the extrusions were 7049, each possessing a different level of purity, one extrusion was a high purity 7050, and the three remaining extrusions were produced to meet the requirements of 7075. Mechanical property data were developed on the extrusions by both Martin Marietta and the Materials Laboratory (AFWAL/MLSA). This report documents the results of the Materials Laboratory's effort and includes, where applicable, some of the results from Martin Marietta. A companion program which dealt with the same alloys but in the -T76511 condition was carried out by Lockheed California (Reference 1).

SECTION II

MATERIAL DESIGNATION

Throughout this report various descriptions and codings are used to define the seven 70XX-T73511 extrusions. A list of these is presented below.

Alloy	AFML Letter Code	Martin Marietta Code	Nomenclature
7049	D	7049A	Hi Purity, high purity Lo Impurity, low impurity
7049	E	7049B	Med Purity, medium purity Med Impurity, medium impurity
7049	F	7049C	Lo Purity, low purity Hi Impurity, high impurity
7050	G	7050A	Hi Purity, high purity Lo Impurity, low impurity
7075	H	7075A	Hi Purity, etc. (see above)
7075	I	7075B	Med Purity, etc.
7075	J	7075C	Lo Purity, etc.

SECTION III

MATERIALS AND SPECIMENS

Prior to this program and in conjunction with several aircraft companies, Martin Marietta (MM) prepared seven ingots of the selected alloys and extruded the ingots to 1.5 x 4.5 inch (3.8 x 11.4 cm) bars. Processing information as supplied by MM is shown in Table 1. Each of the extrusions was checked three times for its chemical composition with the results reported in Tables 2 through 8. Also shown in each table is the registered composition for the alloys. For comparison purposes the registered composition (as reported by the Aluminum Association) of 7075, 7175, and 7475 are shown in Table 9.

Photomicrographs of each of the extrusions are presented in Figures 1, 2, and 3 for the 7049, 7050 and 7075, respectively. The letter designation A, B, and C correspond to the MM designation, i.e., "A" for high purity, "B" for medium purity, and "C" for low purity (Section II).

A part of each of the seven extrusions was sent to the Materials Laboratory to be evaluated for tensile, fatigue, fracture, fatigue crack growth, and corrosion properties. Tensile specimens for the longitudinal and transverse directions had 1/4-inch (0.63 cm) diameter gage sections and the short transverse tensile specimens had 1/8-inch (0.32 cm) diameter gage sections. Fatigue specimens are shown in Figure 4 and the fracture toughness, fatigue crack growth, and corrosion specimens are shown in Figure 5.

SECTION IV

RESULTS AND DISCUSSION

1. TENSILE

The individual and average tensile test results are presented in Tables 10 through 16 for the seven extrusion samples. Table 17 presents the average values from Tables 10 through 16 along with similar results obtained from Martin Marietta (MM). The MM data was obtained from specimens that were removed from the same extrusions that were tested by the AFWAL/MLSA. The general trend within the data is for the ultimate and yield strength to decrease slightly with increased impurity (decreased purity). This is true for both the AFWAL/MLSA and MM data.

One set of tensile results that appear to be completely out of line are those for the short-transverse medium purity level 7049 (Table 11). The raw data and curves for these specimens were inspected and it was determined that there were no errors in them. One of the fractured specimens was used for a chemical analysis which revealed it was removed from the proper plate of material. A conductivity test revealed it had the proper heat treatment. Since there is no reason to discount the validity of these particular results they can be considered correct.

2. FRACTURE TOUGHNESS

Test results from the compact plane strain fracture toughness (K_{IC}) specimens are shown in Tables 18 through 24 with the average values from the tests in the longitudinal (L-T) direction being presented in Table 25 along with similar data from MM. Again a general trend can be observed in the data with the higher purity materials exhibiting the highest toughness. This is true for both directions that were tested. In all cases the transverse (T-L) test results were lower than those for the longitudinal (L-T) tests from the same extrusion.

The change in toughness when going from the high purity to low purity is much greater than was observed for the change in tensile data when

going the same way. The longitudinal toughness for 7049 dropped by about one-third and the transverse dropped about the same. Similar toughness reduction can be observed for the 7075 results. These results indicate a strong dependency exists between impurity elements, in these cases Si and Fe, and fracture toughness, K_{IC}.

3. FATIGUE

Smooth and notched fatigue test results are presented in Figures 6 through 11. Inasmuch as there were a limited number of specimens from each extrusion, it is not possible to make an exact comparison of the effect of purity levels on fatigue life. The smooth 7049 fatigue results show indications that in the high cycle region the high purity extrusion might possess better fatigue characteristics than the other two purity levels while in the low cycle region the effect of purity level is non-existent (data points below 10^7 cycles with arrows pointing to the right indicate the specimens failed in the grip threads). The smooth 7075 data indicated that in the low cycle region there is no effect of purity level, while in the high cycle region it is difficult to detect any trend.

The notched fatigue (K_t = 3.0) data are very consistent and if all seven data sets were overlaid it would not be possible to differentiate between the sets. In the low cycle region all of the data are very uniform irrespective of purity level or alloy and in the high cycle region the stress for a fatigue life at 10^7 cycles appears to be between 15 and 20 KSI (103 and 138 MPa). From the limited fatigue data it can be concluded that there is no dramatic change in fatigue properties caused by purity levels.

4. FATIGUE-CRACK-GROWTH

Fatigue-crack-growth-rate (FCGR) test results from specimens removed from the longitudinal (L-T) direction are shown in Figures 12 through 18. With the exception of high purity 7049 and high purity 7075 there were three specimens tested for this orientation from each extrusion. Two were tested in laboratory air and one in high humidity (R.H. > 90%) air.

For the six cases where high humidity and laboratory air data are available, the trend is for the two sets of data to converge at the lower growth rate regions and diverge at the higher growth rate regions with the high humidity data having the faster growth rate.

In order to compare the FCGR of each data set a straight line was fitted to the laboratory air data in the range of 2×10^{-6} to 2×10^{-5} inch per cycle. The best-fit lines are shown in Figure 19. It can be observed that there is no systematic ranking of the materials from high to low purity and none of the three alloys exhibit unique FCGR characteristics.

Laboratory air FCGR data for the transverse (T-L) orientation are presented in Figures 20 through 26. The same type of comparison that was made for the other orientation is shown in Figure 27 for the transverse data. Again no systematic ranking can be observed for impurity level or alloy. The two best-fit curves to the right on the figure are high purity data sets but this is most likely not a trend but randomness in the data.

5. STRESS CORROSION CRACKING

Stress corrosion cracking test results for the seven extrusions are presented in Table 26. It can be observed that most of the specimens were loaded to stress intensity values that were very close to or above the plane strain fracture toughness, K_{IC}. Some of the specimens that were loaded slightly above the average K_{IC} lasted several hundred hours in the salt water environment. The data indicate there should not be a corrosion problem with these alloys in the L-T and T-L orientations in the T73511 condition.

SECTION V

CONCLUSIONS

For the extrusions tested in this program the following trends in the data were observed:

A slight decrease in strength was observed when going from high purity to low purity.

A marked decrease in toughness was observed when going from high to low purity.

Notched fatigue data indicate all of the extrusions possess similar properties.

No well defined trends could be observed in the smooth fatigue data.

Fatigue crack growth rate data did not show purity level to have a systematic effect on properties.

High humidity air caused an increase in the FCGR for all of the extrusions.

Stress corrosion does not appear to be a problem for the alloys and heat treatment tested.

REFERENCE

1. J. T. Ryder and J. M. Van Orden, "Effect of Purity on Fatigue and Fracture of 7XXX-T76511 Aluminum Extrusions," Lockheed California Company, Report No. LR 28612, May 1978.

TABLE 1

EXTRUSION PROCESSING INFORMATION FROM MARTIN MARIETTA

PROCESSING PROCEDURES

7XXX-T73511 ALLOY 1.5" X 4.5" EXTRUDED RECTANGLES

ALLOY	CODE	EXTRUSION RATIO	EXTRUSION INGOT TEMP. °F	CONTAINER TEMP. °F	PRECIPITATION TREATMENTS* INITIAL °F	INITIAL HRS.	SECONDARY °F	SECONDARY HRS.	CONDUCTIVITY % IACS
7075	A	10.2	770	750	250	24	345	7.5	40.2
7075	B	"	800	"	"	"	"	7.5	40.7
7075	C	"	790	"	"	"	"	7.5	40.0
7049	A	"	760	"	250	24	340	6.	40.3
7049	B	"	770	"	"	"	"	6.	40.5
7049	C	"	750	"	"	"	"	6.	40.1
7050	A	"	770	"	250	24	325	32	40.0

* Solution heat treatment consisted of 1-1/2 hours at 870°F followed by a cold water quench and a 2% permanent set in stretching.

TABLE 2

CHEMICAL COMPOSITION OF 7049-T73511 HIGH PURITY ALUMINUM EXTRUSION

(WT. %)

SOURCE*	Si	Fe	Cu	Mg	Zn	Cr	Mn	Zr	Pb	Ti	Ni
AFWAL/MLSA	0.036	0.080	1.410	2.370	8.070	0.160	0.011	<0.010	0.110	0.004	0.004
AFWAL/MLSA	0.042	0.091	1.450	2.350	8.040	0.170	0.013	<0.010	0.110	0.004	0.004
M.M	0.080	0.090	1.50	2.490	7.750	0.210	0.010	0.000	0.040	0.010	0.000
AA (MIN.)	----	----	1.200	2.000	7.200	0.100	----			----	
AA (MAX.)	0.250	0.350	1.900	2.900	8.200	0.220	0.200			0.100	

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

MM: MARTIN MARIETTA

AA: ALUMINUM ASSOCIATION LIMITS

TABLE 3

CHEMICAL COMPOSITION OF 7049-T73511 MEDIUM PURITY ALUMINUM EXTRUSION

(WT. %)

SOURCE*	Si	Fe	Cu	Mg	Zn	Cr	Mn	Zr	Pb	Ti	Ni
AFWAL/MLSA	0.072	0.180	1.560	2.280	7.940	0.160	0.013	<0.010	0.120	0.004	0.004
AFWAL/MLSA	0.080	0.150	1.530	2.250	7.920	0.150	0.013	<0.010	0.100	0.004	0.004
M.M	0.110	0.200	1.600	2.350	7.920	0.200	0.010	0.000	0.040	0.010	0.000
AA (MIN.)	----	----	1.200	2.000	7.200	0.100	----			----	
AA (MAX.)	0.250	0.350	1.900	2.900	8.200	0.220	0.200			0.100	

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

MM: MARTIN MARIETTA

AA: ALUMINUM ASSOCIATION LIMITS

TABLE 4

CHEMICAL COMPOSITION OF 7049-T73511 LOW PURITY ALUMINUM EXTRUSION

(WT. %)

SOURCE*	Si	Fe	Cu	Mg	Zn	Cr	Mn	Zr	Pb	Ti	Ni
AFWAL/MLSA	0.089	0.170	1.590	2.270	8.090	0.110	0.015	<0.010	0.100	0.004	0.003
AFWAL/MLSA	0.120	0.200	1.560	2.340	8.110	0.140	0.016	<0.010	0.100	0.005	0.003
MM	0.160	0.370	1.600	2.310	7.800	0.190	0.020	0.000	0.040	0.010	0.000
AA (MIN.)	----	----	1.200	2.000	7.200	0.100	----			----	
AA (MAX.)	0.250	0.350	1.900	2.900	8.200	0.220	0.200			0.100	

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

MM: MARTIN MARIETTA

AA: ALUMINUM ASSOCIATION LIMITS

TABLE 5

CHEMICAL COMPOSITION OF 7050-T73511 HIGH PURITY ALUMINUM EXTRUSION

(WT. %)

SOURCE*	Si	Fe	Cu	Mg	Zn	Cr	Mn	Zr	Pb	Ti	Ni
AFWAL/MLSA	0.048	0.089	2.200	2.400	6.470	0.006	0.013	0.068	0.046	0.003	0.006
AFWAL/MLSA	0.046	0.080	2.260	2.280	6.450	0.007	0.012	0.071	0.039	0.003	0.006
M.M	0.050	0.100	2.300	2.400	6.350	0.030	0.010	0.120	0.020	0.010	0.010
AA (MIN.)	----	----	2.000	1.900	5.700	----		0.080		----	
AA (MAX.)	0.120	0.150	2.600	2.600	6.700	0.040	0.100	0.150		0.060	

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

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AA: ALUMINUM ASSOCIATION LIMITS

TABLE 6

CHEMICAL COMPOSITION OF 7075-T73511 HIGH PURITY ALUMINUM EXTRUSION

(WT. %)

SOURCE*	Si	Fe	Cu	Mg	Zn	Cr	Mn	Zr	Pb	Ti	Ni
AFWAL/MLSA	0.034	0.078	1.410	2.290	5.530	0.140	0.008	<0.010	0.007	0.003	0.002
AFWAL/MLSA	0.034	0.066	1.490	2.420	5.790	0.140	0.008	<0.010	0.008	0.003	0.002
M.M	0.080	0.110	1.400	2.400	6.030	0.200	0.010	0.000	0.000	0.010	0.000
AA (MIN.)	----	----	1.200	2.100	5.100	0.180	----			----	
AA (MAX.)	0.400	0.500	2.000	2.900	6.100	0.280	0.300			0.200	

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

MM. MARTIN MARIETTA

AA: ALUMINUM ASSOCIATION LIMITS

TABLE 7

CHEMICAL COMPOSITION OF 7075-T73511 MEDIUM PURITY ALUMINUM EXTRUSION

(WT. %)

SOURCE*	Si	Fe	Cu	Mg	Zn	Cr	Mn	Zr	Pb	Ti	Ni
AFWAL/MLSA	0.100	0.190	1.500	2.330	5.530	0.180	0.024	<0.010	0.054	0.011	0.006
AFWAL/MLSA	0.088	0.170	1.520	2.250	5.720	0.160	0.022	<0.010	0.046	0.010	0.005
M.M	0.130	0.210	1.430	2.410	5.850	0.200	0.010	0.010	0.030	0.010	0.000
AA (MIN.)	----	----	1.200	2.100	5.100	0.180	----			----	
AA (MAX.)	0.400	0.500	2.000	2.900	6.100	0.280	0.300			0.200	

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

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TABLE 8

CHEMICAL COMPOSITION OF 7075-T73511 LOW PURITY ALUMINUM EXTRUSION

(WT. %)

SOURCE*	Si	Fe	Cu	Mg	Zn	Cr	Mn	Zr	Pb	Ti	Ni
AFWAL/MLSA	0.140	0.260	1.500	2.340	5.700	0.190	0.024	<0.010	0.044	0.014	0.006
AFWAL/MLSA	0.140	0.290	1.410	2.340	5.560	0.190	0.024	<0.010	0.044	0.011	0.004
MM	0.170	0.330	1.600	2.400	6.00	0.200	0.020	0.000	0.030	0.010	0.010
AA (MIN.)	----	----	1.200	2.100	5.100	0.180	----			----	
AA (MAX.)	0.400	0.500	2.000	2.900	6.100	0.280	0.300			0.200	

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

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AA: ALUMINUM ASSOCIATION LIMITS

TABLE 9

COMPARISON OF CHEMICAL COMPOSITION LIMITS FOR 7X75 ALUMINUM ALLOYS

(WT. %)

ALLOY*	Si	Fe	Cu	Mg	Zn	Cr	Mn	Zr	Pb	Ti	Ni
7075 (AA MIN.)	--	--	1.200	2.100	5.100	0.180	--			--	
7075 (AA MAX.)	0.400	0.500	2.000	2.900	6.100	0.280	0.300			0.200	
7175 (AA MIN.)	--	--	1.200	2.100	5.100	0.180	--			--	
7175 (AA MAX.)	0.150	0.200	2.000	2.900	6.100	0.280	0.100			0.100	
7475 (AA MIN.)	--	--	1.200	1.900	5.200	0.180	--			--	
7475 (AA MAX.)	0.100	0.120	1.900	2.600	6.200	0.250	0.060			0.060	

* AA = ALUMINUM ASSOCIATION LIMITS

TABLE 10

TENSILE TEST RESULTS FOR HIGH PURITY 7049-T73511

GRAIN ORIENTATION	ULTIMATE STRENGTH		YIELD STRENGTH		ELONGATION, %	REDUCTION OF AREA, %
	KSI	MPa	KSI	MPa		
LONGITUDINAL	82.5	569	75.1	518	13.3	34.1
	84.5	583	77.4	534	13.3	35.4
	84.8	585	77.7	536	13.0	37.3
AVG.	83.9	579	76.7	529	13.3	35.6
TRANSVERSE	78.0	538	69.8	481	12.3	26.5
	78.3	540	70.1	483	11.9	26.6
	79.1	545	70.9	489	13.4	27.3
AVG.	78.5	541	70.3	484	12.5	26.8
SHORT TRANS.	74.8	516	65.3	450	9.0	13.0
	74.8	516	----	---	7.0	11.0
	74.7	515	65.2	450	8.0	11.0
AVG.	74.8	515	65.3	450	8.0	11.7

TABLE 11

TENSILE TEST RESULTS FOR MEDIUM PURITY 7049-T73511

GRAIN ORIENTATION	ULTIMATE STRENGTH		YIELD STRENGTH		ELONGATION, %	REDUCTION OF AREA, %
	KSI	MPa	KSI	MPa		
LONGITUDINAL	81.0	558	73.7	508	12.5	27.9
	83.7	577	76.8	530	12.2	28.1
	82.7	570	75.6	521	12.5	33.3
AVG.	82.5	568	75.4	520	12.4	29.8
TRANSVERSE	76.8	530	69.1	476	11.0	19.6
	76.7	529	69.1	476	10.5	18.9
	76.0	524	69.4	479	10.1	16.0
AVG.	76.5	528	69.2	477	10.5	18.2
SHORT TRANS.	51.0	352	34.5	238	13.0	17.0
	57.5	396	42.5	293	11.0	12.0
	53.8	371	38.1	263	10.0	15.0
AVG.	54.1	373	38.4	265	11.3	14.7

TABLE 12

TENSILE TEST RESULTS FOR LOW PURITY 7049-T73511

GRAIN ORIENTATION	ULTIMATE STRENGTH		YIELD STRENGTH		ELONGATION, %	REDUCTION OF AREA, %
	KSI	MPa	KSI	MPa		
LONGITUDINAL	79.3	547	72.1	497	11.6	24.6
	79.9	551	73.1	504	11.8	28.7
	80.8	557	74.2	512	11.4	28.0
AVG.	80.0	552	73.1	504	11.6	27.1
TRANSVERSE	75.4	520	68.3	471	9.4	10.8
	75.6	521	68.3	471	8.7	10.8
	76.1	525	69.1	476	9.0	13.1
AVG.	75.7	522	68.6	473	9.0	11.6
SHORT TRANS.	68.2	470	62.8	433	---	----
	69.3	478	61.8	426	6.0	5.0
	70.2	484	62.4	430	4.0	5.0
AVG.	69.2	477	62.3	430	5.0	5.0

TABLE 13

TENSILE TEST RESULTS FOR HIGH PURITY 7050-T73511

GRAIN ORIENTATION	ULTIMATE STRENGTH		YIELD STRENGTH		ELONGATION, %	REDUCTION OF AREA, %
	KSI	MPa	KSI	MPa		
LONGITUDINAL	80.1	552	71.6	494	14.2	36.5
	80.4	554	72.5	500	14.1	38.4
	80.4	554	72.4	499	13.7	35.9
AVG.	80.3	553	72.1	498	14.0	36.9
TRANSVERSE	76.0	524	67.3	464	12.4	27.3
	74.3	512	65.6	452	10.7	16.0
	76.3	526	67.0	462	13.1	26.0
AVG.	75.5	521	66.6	459	12.1	23.1
SHORT TRANS.	72.4	500	62.5	431	10.0	8.0
	74.0	510	63.7	439	9.0	9.0
	74.2	512	63.3	436	7.0	9.0
AVG.	73.5	507	63.2	435	8.7	8.7

TABLE 14

TENSILE TEST RESULTS FOR HIGH PURITY 7075-T73511

GRAIN ORIENTATION	ULTIMATE STRENGTH		YIELD STRENGTH		ELONGATION, %	REDUCTION OF AREA, %
	KSI	MPa	KSI	MPa		
LONGITUDINAL	77.6	535	68.1	470	15.3	40.9
	78.1	538	69.4	479	14.2	41.6
	77.5	534	68.5	472	14.9	42.7
AVG.	77.7	536	68.6	473	14.8	41.7
TRANSVERSE	73.0	503	62.7	432	13.5	27.4
	73.2	505	63.1	435	13.3	30.7
	73.0	503	63.1	435	12.6	29.4
AVG.	73.1	504	63.0	434	13.1	29.2
SHORT TRANS.	70.2	484	52.8	399	10.0	15.0
	70.0	483	57.9	399	7.0	12.0
	68.9	475	57.7	398	9.0	14.0
AVG.	69.7	481	57.8	399	8.7	13.7

TABLE 15

TENSILE TEST RESULTS FOR MEDIUM PURITY 7075-T73511

GRAIN ORIENTATION	ULTIMATE STRENGTH KSI	ULTIMATE STRENGTH MPa	YIELD STRENGTH KSI	YIELD STRENGTH MPa	ELONGATION, %	REDUCTION OF AREA, %
LONGITUDINAL	76.8	530	67.8	467	13.6	34.1
	75.4*	520*	74.6*	514*	13.6*	37.8*
	77.2	532	68.9	475	12.9	31.3
AVG.	77.0	531	68.4	471	13.3	32.7
TRANSVERSE	72.4	499	62.2	429	12.1	23.9
	72.3	499	62.8	433	12.6	24.0
	72.3	499	63.5	438	12.1	22.5
AVG.	72.3	499	62.9	433	12.3	23.5
SHORT TRANS.	69.3	478	58.8	405	10.0	9.0
	70.1	483	58.6	404	9.0	10.0
	70.1	483	59.1	407	8.0	6.0
AVG.	69.8	482	58.8	405	9.0	8.3

* Run at 5 in/min, instead of .05"/min (not incl. in AVG.)

TABLE 16

TENSILE TEST RESULTS FOR LOW PURITY 7075-T73511

GRAIN ORIENTATION	ULTIMATE STRENGTH		YIELD STRENGTH		ELONGATION, %	REDUCTION OF AREA, %
	KSI	MPa	KSI	MPa		
LONGITUDINAL	73.4	506	64.5	445	12.3	27.3
	73.9	510	65.5	452	12.6	33.2
	74.4	513	66.1	456	13.3	35.2
AVG.	73.9	510	65.3	451	12.7	31.9
TRANSVERSE	70.5	486	61.1	421	11.5	20.4
	70.0	483	60.7	419	12.3	22.5
	69.9	482	60.9	420	11.2	19.6
AVG.	70.2	484	60.9	420	11.7	20.8
SHORT TRANS.	66.2	456	56.9	392	----	----
	67.5	465	57.5	396	7.0	9.0
	67.4	465	57.3	395	6.0	7.0
AVG.	67.0	462	57.2	394	6.5	8.0

TABLE 17

COMPARISON OF TENSILE DATA FOR 7XXX-T73511 ALUMINUM EXTRUSIONS

MATERIAL	ORIENTATION	ULTIMATE STRENGTH AFML* KSI	ULTIMATE STRENGTH AFML* MPa	ULTIMATE STRENGTH MM* KSI	ULTIMATE STRENGTH MM* MPa	YIELD STRENGTH AFWAL/MLSA* KSI	YIELD STRENGTH AFWAL/MLSA* MPa	YIELD STRENGTH MM* KSI	YIELD STRENGTH MM* MPa
7049 (HIGH PURITY)	LONGITUDINAL	83.9	579	80.6	556	76.7	529	72.1	497
	TRANSVERSE	78.5	541	76.7	529	70.3	484	68.0	529
7049 (MED. PURITY)	LONGITUDINAL	82.5	568	80.4	554	75.4	520	72.9	503
	TRANSVERSE	76.5	528	75.5	521	69.2	477	67.7	521
7049 (LOW PURITY)	LONGITUDINAL	80.0	552	77.7	536	73.1	504	69.9	482
	TRANSVERSE	75.7	522	72.8	502	68.6	473	64.7	502
7050 (HIGH PURITY)	LONGITUDINAL	80.3	553	78.7	543	72.1	498	70.0	483
	TRANSVERSE	75.5	521	75.2	518	66.6	459	66.2	518
7075 (HIGH PURITY)	LONGITUDINAL	77.7	536	77.2	532	68.6	473	68.2	470
	TRANSVERSE	73.1	504	72.7	501	63.0	434	63.1	501
7075 (MED. PURITY)	LONGITUDINAL	77.0	531	76.4	527	68.4	471	68.0	469
	TRANSVERSE	72.3	499	72.3	498	62.9	433	63.3	498
7075 (LOW PURITY)	LONGITUDINAL	73.9	510	75.6	521	65.3	451	67.2	463
	TRANSVERSE	70.2	484	71.0	490	60.9	420	62.5	490

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

MM: MARTIN MARIETTA

TABLE 18

FRACTURE TOUGHNESS TEST RESULTS FOR 7049-T73511 (HIGH PURITY)

ORIENTATION	P_{max}/P_Q	K_{Ic} KSI $\sqrt{in.}$	K_{Ic} MPa $\sqrt{m.}$
LONGITUDINAL (L-T)	1.00	34.0	37.4
	1.00	33.8	37.1
AVG.	1.00	33.9	37.2
TRANSVERSE (T-L)	1.00	26.0	28.6
	1.00	25.9	28.5
AVG.	1.00	26.0	28.6

TABLE 19

FRACTURE TOUGHNESS TEST RESULTS FOR 7049-T73511 (MED. PURITY)

ORIENTATION	P_{max}/P_Q	K_{Ic} KSI $\sqrt{in.}$	K_{Ic} MPa $\sqrt{m.}$
LONGITUDINAL (L-T)	1.00	30.3	33.3
	1.00	29.1	32.0
AVG.	1.00	29.7	32.6
TRANSVERSE (T-L)	1.00	21.7	23.8
	1.00	22.4	24.6
AVG.	1.00	22.1	24.3

TABLE 20

FRACTURE TOUGHNESS TEST RESULTS FOR 7049-T73511 (LOW PURITY)

ORIENTATION	P_{max}/P_Q	K_{Ic} KSI $\sqrt{in.}$	K_{Ic} MPa $\sqrt{m.}$
LONGITUDINAL (L-T)	1.00	24.0	26.4
	1.00	23.6	25.9
AVG.	1.00	23.8	26.2
TRANSVERSE (T-L)	1.00	18.2	20.0
	1.00	18.0	19.8
AVG.	1.00	18.1	19.9

TABLE 21

FRACTURE TOUGHNESS TEST RESULTS FOR 7050-T73511 (HIGH PURITY)

ORIENTATION	P_{max}/P_Q	K_{Ic} KSI $\sqrt{in.}$	K_{Ic} MPa $\sqrt{m.}$
LONGITUDINAL (L-T)	1.00	38.4	42.2
	1.00	33.9	37.2
AVG.	1.00	36.2	39.8
TRANSVERSE (T-L)	1.00	24.2	26.6
	1.00	23.9	26.3
AVG.	1.00	24.1	26.5

TABLE 22

FRACTURE TOUGHNESS TEST RESULTS FOR 7075-T73511 (HIGH PURITY)

ORIENTATION	P_{max}/P_Q	K_{Ic} KSI $\sqrt{in.}$	K_{Ic} MPa $\sqrt{m.}$
LONGITUDINAL	1.00	44.2	48.6
(L-T)	1.00	41.8	45.9
AVG.	1.00	43.0	47.2
TRANSVERSE	1.00	30.0	33.0
(T-L)	1.00	29.9	32.9
AVG.	1.00	30.0	33.0

TABLE 23

FRACTURE TOUGHNESS TEST RESULTS FOR 7075-T73511 (MED. PURITY)

ORIENTATION	P_{max}/P_Q	K_{Ic} KSI $\sqrt{in.}$	K_{Ic} MPa $\sqrt{m.}$
LONGITUDINAL	1.00	30.4	33.4
(L-T)	1.05	30.7	33.7
AVG.	1.03	30.6	33.6
TRANSVERSE	1.00	21.7	23.8
(T-L)	1.00	22.1	24.3
AVG.	1.00	21.9	24.1

TABLE 24

FRACTURE TOUGHNESS TEST RESULTS FOR 7075-T73511 (LOW PURITY)

ORIENTATION	P_{max}/P_Q	K_{Ic} KSI $\sqrt{in.}$	K_{Ic} MPa $\sqrt{m.}$
LONGITUDINAL (L-T)	1.01 1.03	27.1 27.4	29.8 30.1
AVG.	1.02	27.3	30.0
TRANSVERSE (T-L)	1.00 1.00	20.5 22.9	22.5 25.2
AVG.	1.00	21.7	23.8

TABLE 25

COMPARISON OF FRACTURE TOUGHNESS DATA FOR 7XXX-T73511 ALUMINUM EXTRUSIONS

MATERIAL	ORIENTATION	K_{Ic} AFWAL/MLSA* KSI $\sqrt{in.}$	K_{Ic} AFWAL/MLSA* MPa $\sqrt{m}$	K_{Ic} MM* KSI $\sqrt{in.}$	K_{Ic} MM* MPa $\sqrt{m}$
7049 (HIGH PURITY)	LONGITUDINAL (L-T)	33.9	37.2	35.0	38.4
7049 (MED. PURITY)	LONGITUDINAL (L-T)	29.7	32.6	30.5	33.5
7049 (LOW PURITY)	LONGITUDINAL (L-T)	23.8	26.2	25.6	28.1
7050 (HIGH PURITY)	LONGITUDINAL (L-T)	36.2	39.8	38.1	41.9
7075 (HIGH PURITY)	LONGITUDINAL (L-T)	43.0	47.2	41.5	45.6
7075 (MED. PURITY)	LONGITUDINAL (L-T)	30.6	33.6	31.8	34.9
7075 (LOW PURITY)	LONGITUDINAL (L-T)	27.3	30.0	27.1	29.8

* AFWAL/MLSA: AIR FORCE WRIGHT AERONAUTICAL LABORATORIES, MATERIALS LABORATORY

* MM: MARTIN MARIETTA

TABLE 26

STRESS CORROSION TEST RESULTS FOR 7XXX-T73511 ALUMINUM EXTRUSIONS
CONSTANT LOAD, CONSTANT IMMERSION

3.5 percent NaCl Solution

MATERIAL	ORIENTATION	K_{INITAL}* KSI $\sqrt{in}$	K_{INITAL}* MPa $\sqrt{in}$	K_I / K_{IC}	TIME (HR)	COMMENTS
7049 (HIGH PURITY)	LONGITUDINAL L-T	25	27	.74	166	NO FAILURE
		30	33	.88	652	NO FAILURE
	TRANSVERSE T-L	27.1	29.8	1.04	0	FAILED ON LOADING
		26.5	29.1	1.02	0	FAILED ON LOADING
7049 (MED. PURITY)	LONGITUDINAL L-T	30.1	33.1	1.01	840	NO FAILURE
	TRANSVERSE T-L	22.5	24.7	1.01	1	
		24.7	27.1	1.12	0	FAILED ON LOADING
7049 (LOW PURITY)	LONGITUDINAL L-T	25.9	28.5	1.01	533	NO FAILURE
	TRANSVERSE T-L	18.3	20.1	1.01	331	
		18.2	20.0	1.00	262	
7050 (HIGH PURITY)	LONGITUDINAL L-T	25	27	.69	652	NO FAILURE
		35.1	38.6	.97	882	NO FAILURE
	TRANSVERSE T-L	*28.4	31.2	1.18	0	FAILED ON LOADING
		23.8	26.2	.99	395	
7075 (HIGH PURITY)	LONGITUDINAL L-T	25	27	.58	551	NO FAILURE
	TRANSVERSE T-L	34.5	37.9	1.15	0	FAILED ON LOADING
		30.4	33.4	1.01	1601	NO FAILURE
7075 (MED. PURITY)	LONGITUDINAL L-T	33.1	36.4	1.08	860	NO FAILURE
	TRANSVERSE T-L	24.9	27.4	1.14	0	FAILED ON LOADING
		22.0	24.2	1.00	1485	NO FAILURE
7075 (LOW PURITY)	LONGITUDINAL L-T	25	27	.91	529	NO FAILURE
	TRANSVERSE T-L	21.0	23.1	.97	2446	NO FAILURE
		22	24.2	1.01	1171	NO FAILURE

* Whole numbers are estimate.

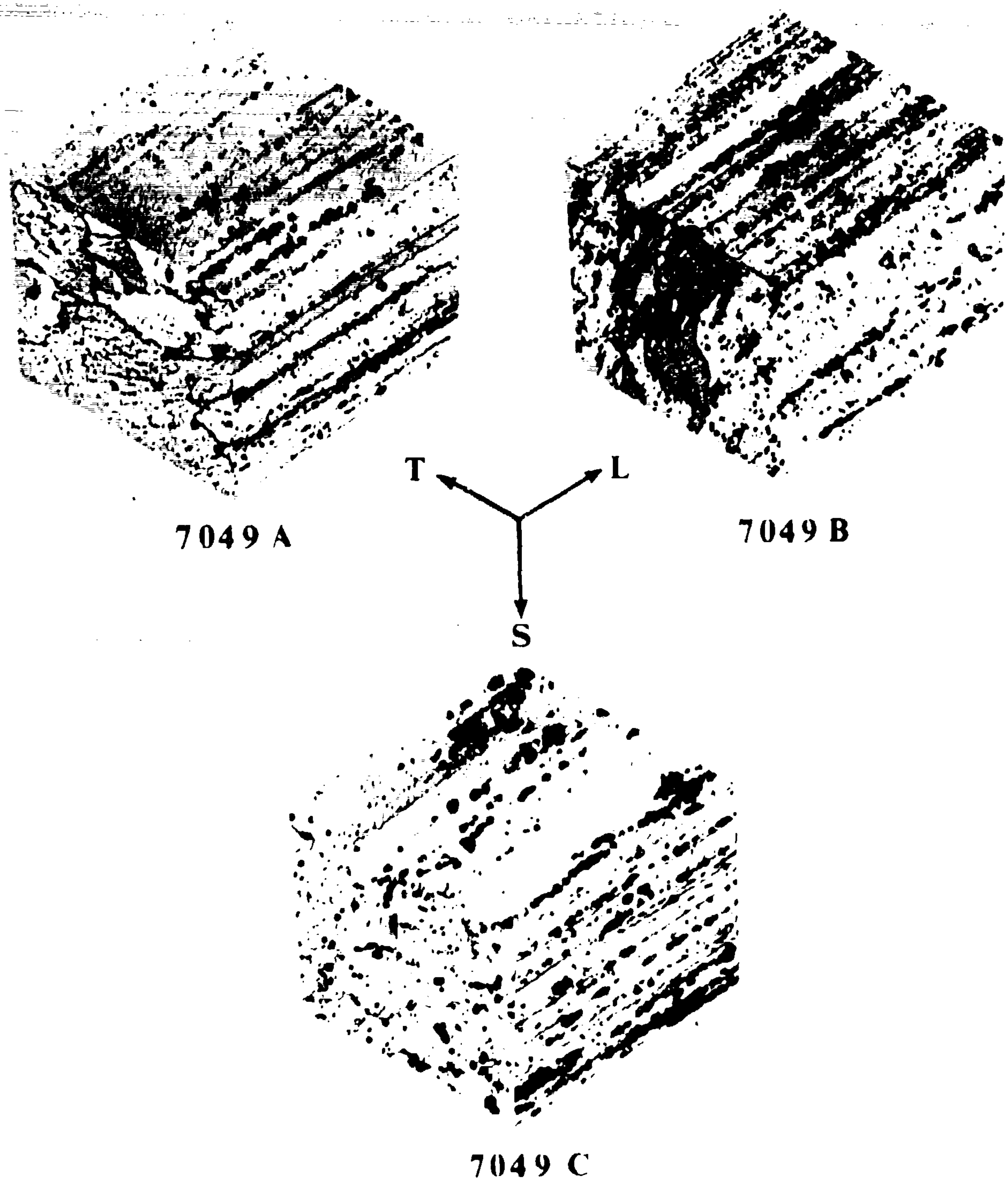


Figure 1. Photomicrographs of the Three 7049-T73511 Extrusions

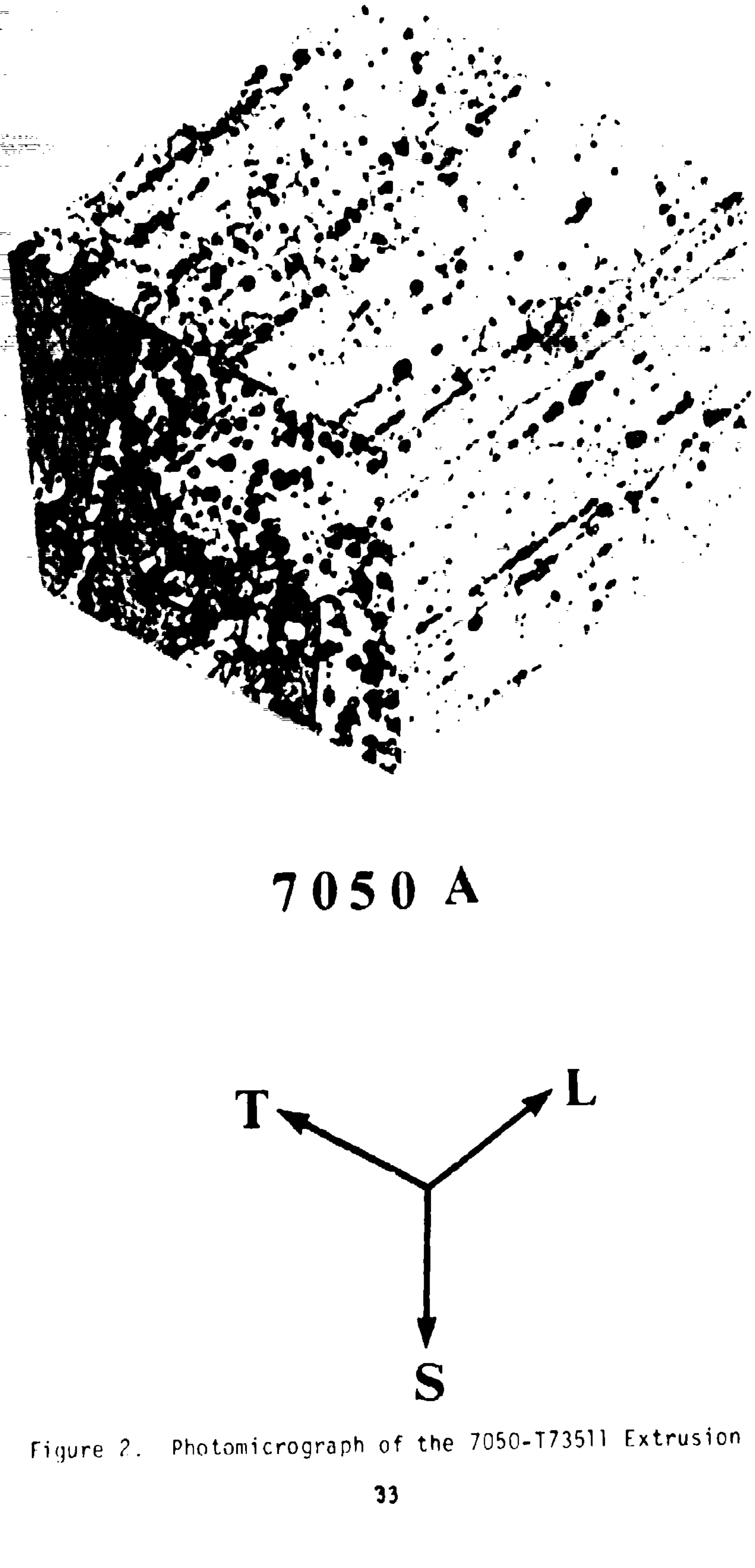


Figure 2. Photomicrograph of the 7050-T73511 Extrusion

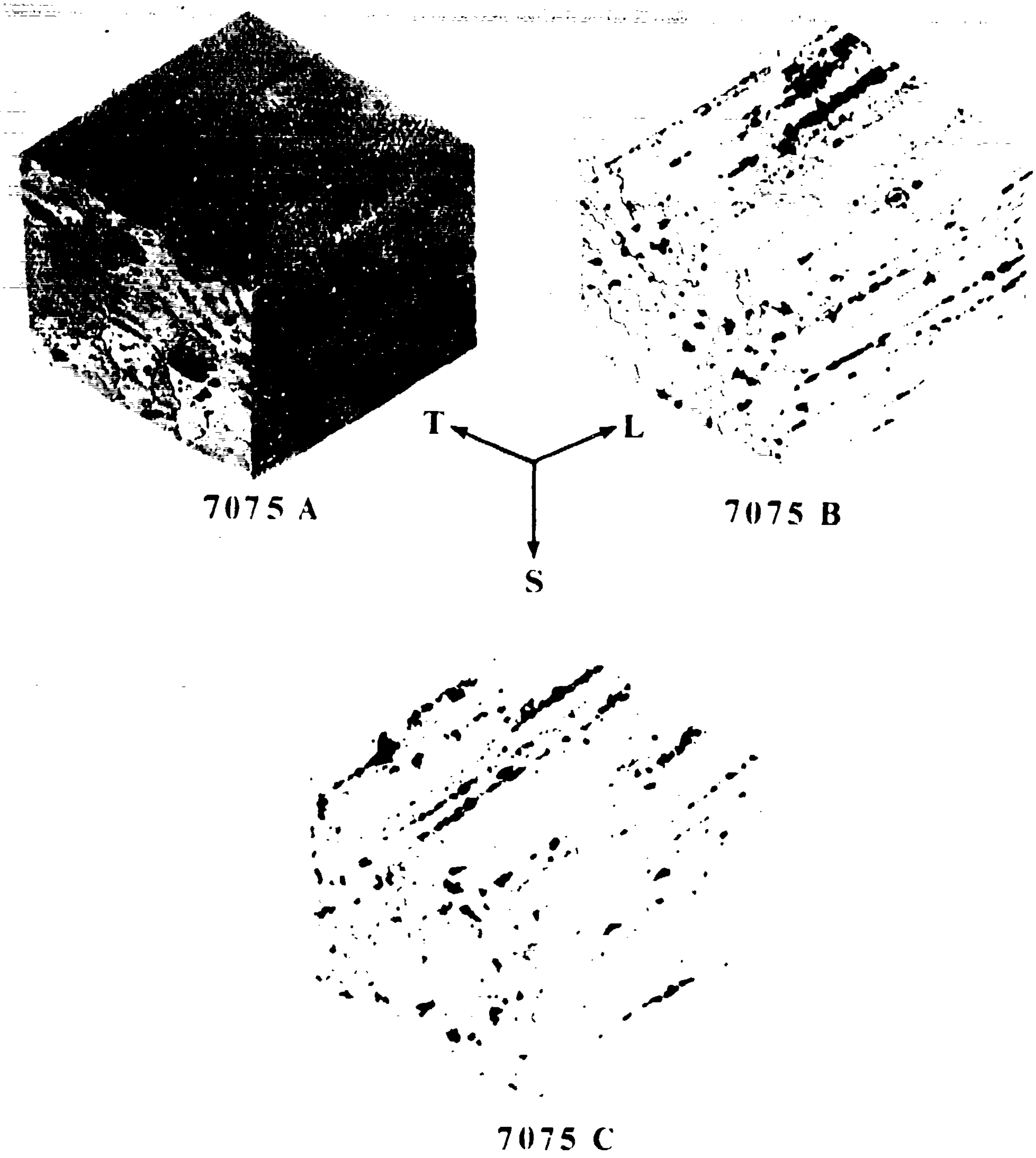


Figure 3. Photomicrograph of the Three 7075-T73511 Extrusions

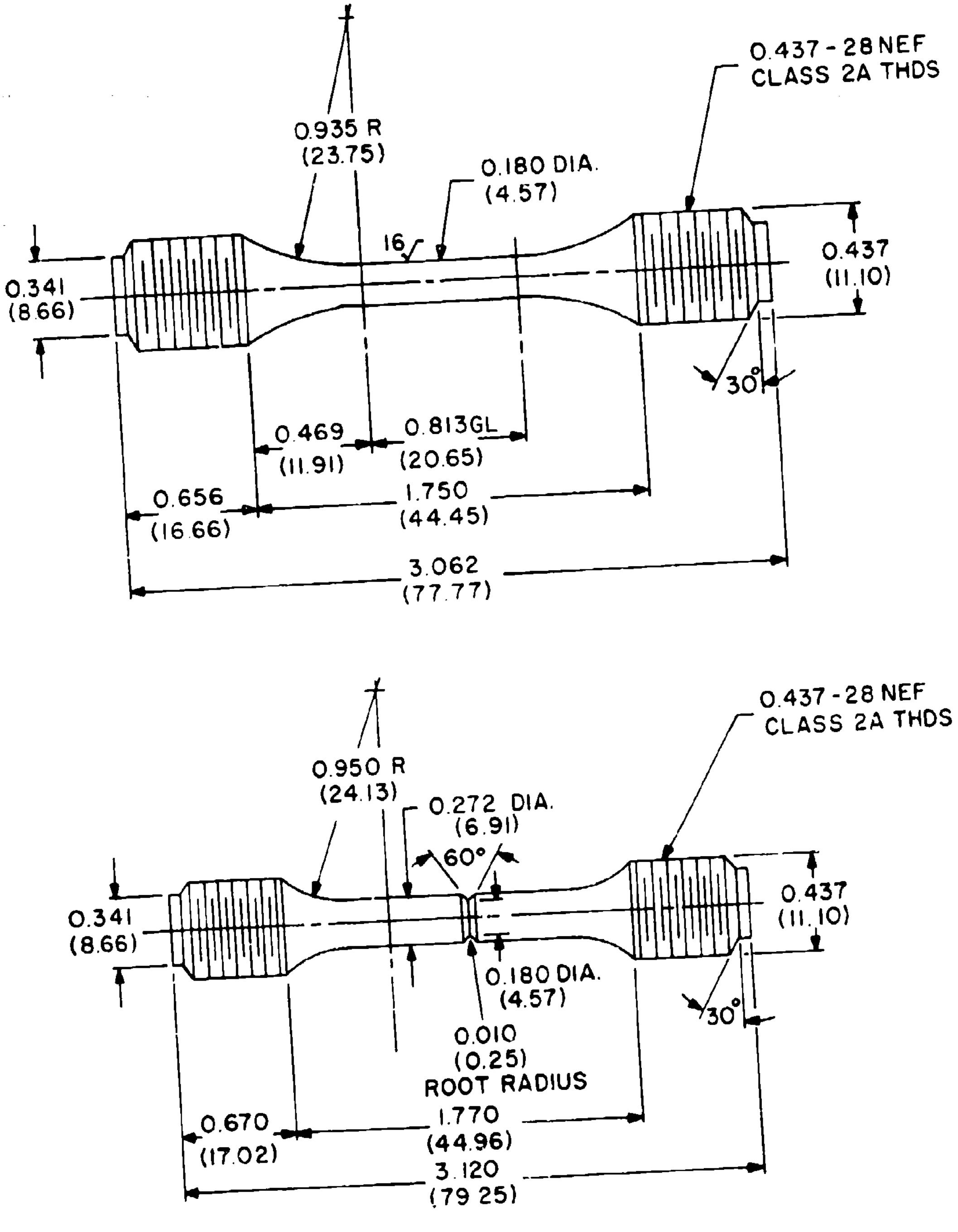
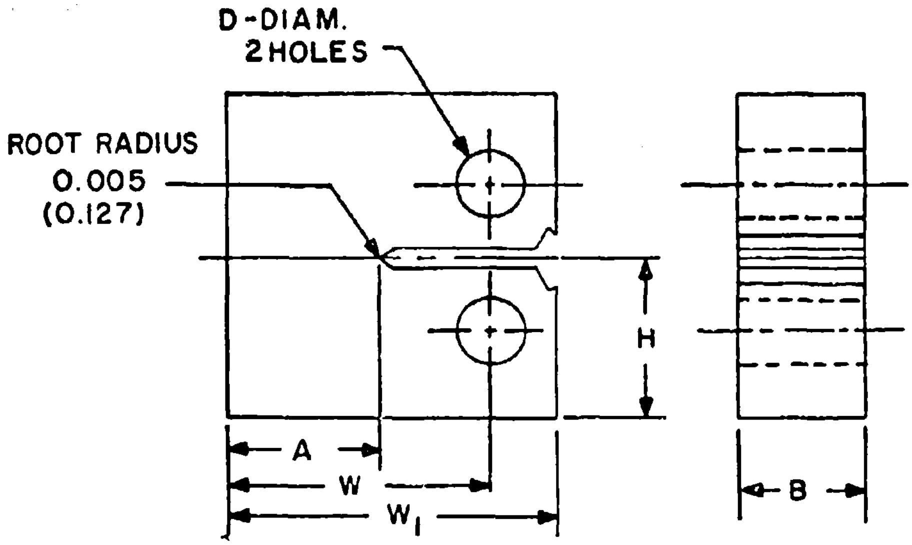


Figure 4. Fatigue Specimens: Top, Smooth; Bottom, Notched



DIMENSIONS: INCHES (mm)

SPECIMEN TYPE	A	B	W	W_1	H	D
FRACTURE TOUGHNESS	1.50 (38.1)	1.25 (31.7)	2.5 (63.5)	3.125 (79.37)	1.5 (38.1)	0.625 (15.9)
CRACK GROWTH*	1.785 (45.3)	0.625 (15.9)	2.55 (64.8)	3.188 (80.9)	1.240 (31.5)	0.50 (12.7)
CORROSION	1.50 (38.1)	0.625 (15.9)	2.500 (63.5)	3.125 (79.37)	1.5 (38.1)	0.625 (15.9)

Figure 5. Fracture Toughness, Fatigue Crack Growth, and Stress Corrosion Specimens

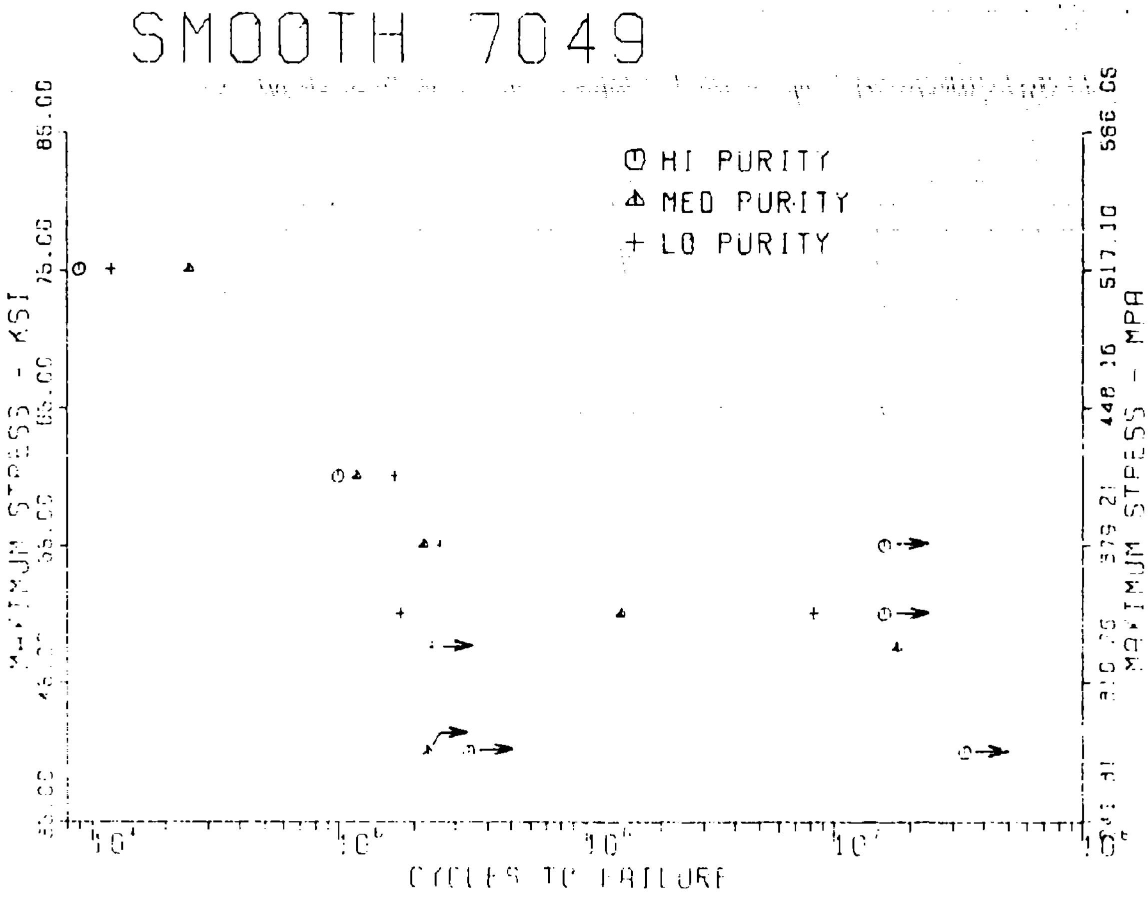


Figure 5. Smooth Fatigue Test Results for 7049 Extrusions, Laboratory Air, R = 0.1

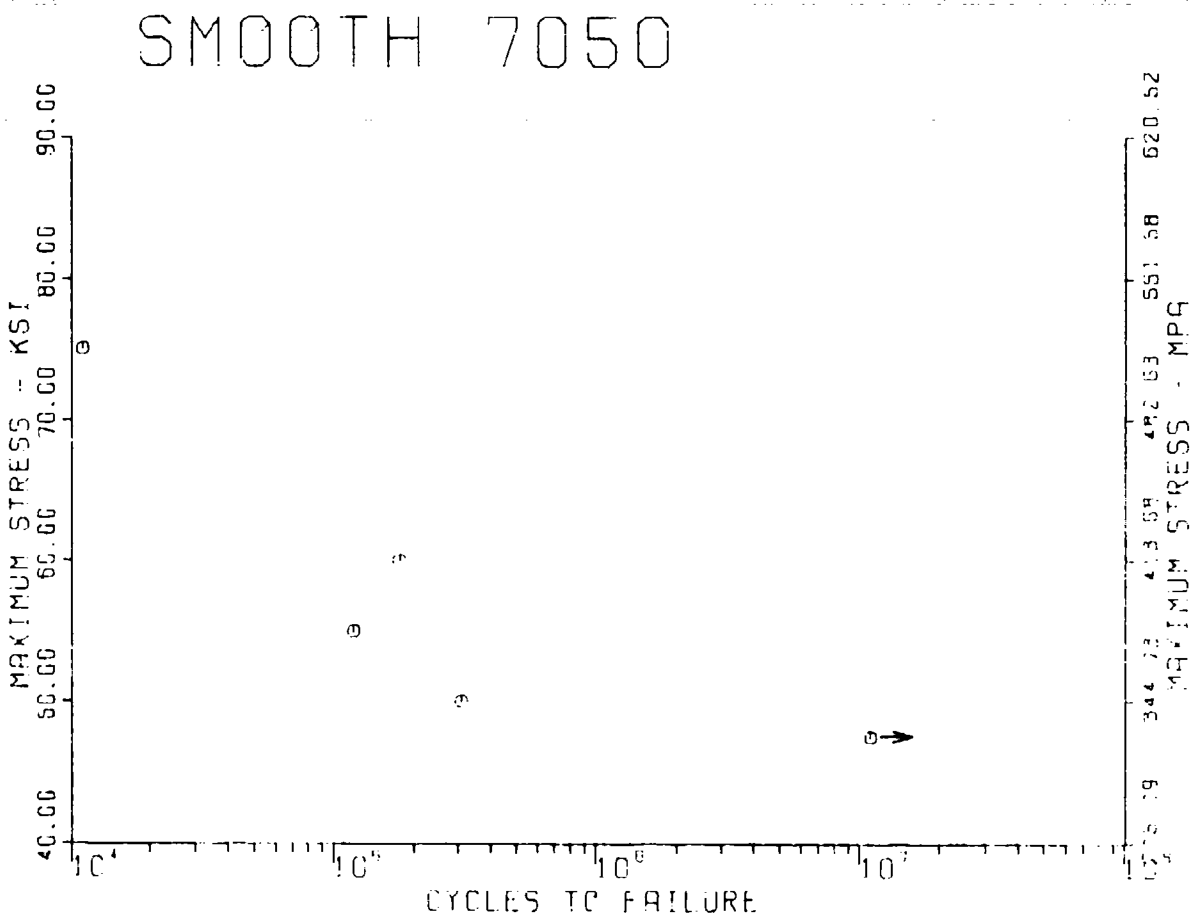


Figure 7. Smooth Fatigue Test Results for 7050 Extrusions, Laboratory Air, R = 0.1

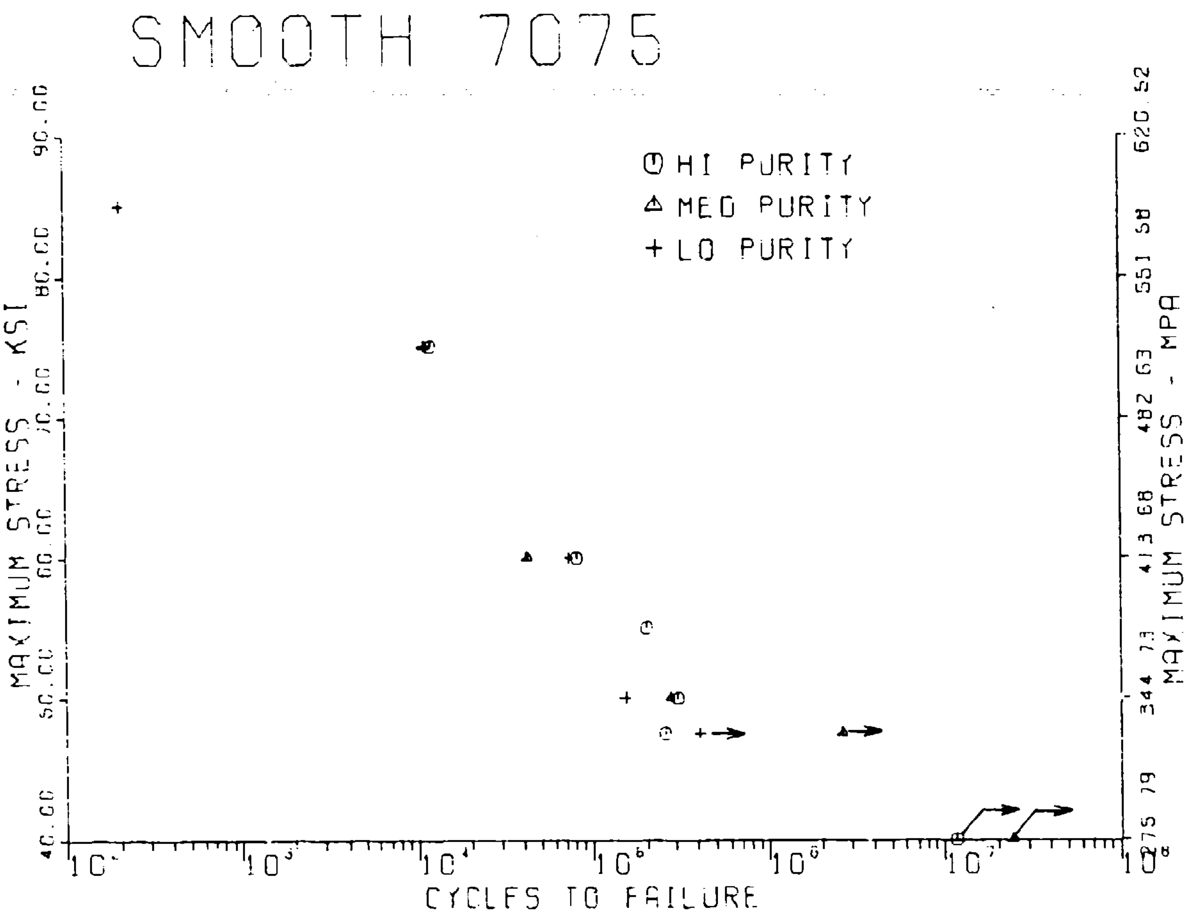


Figure 8. Smooth Fatigue Test Results for 7075 Extrusions, Laboratory Air, R = 0.1

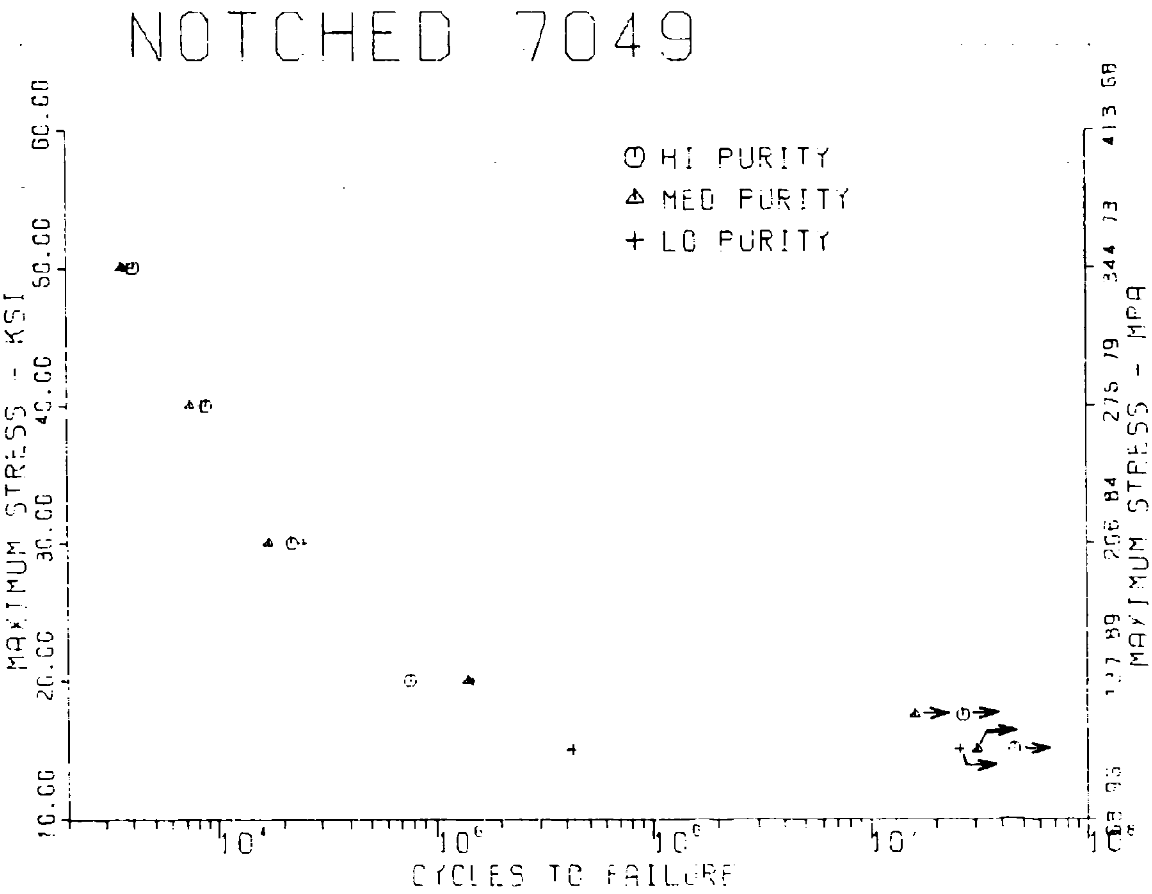


Figure 9. Notched Fatigue Test Results for 7049 Extrusions; Laboratory Air, R = 0.1, K_t = 3

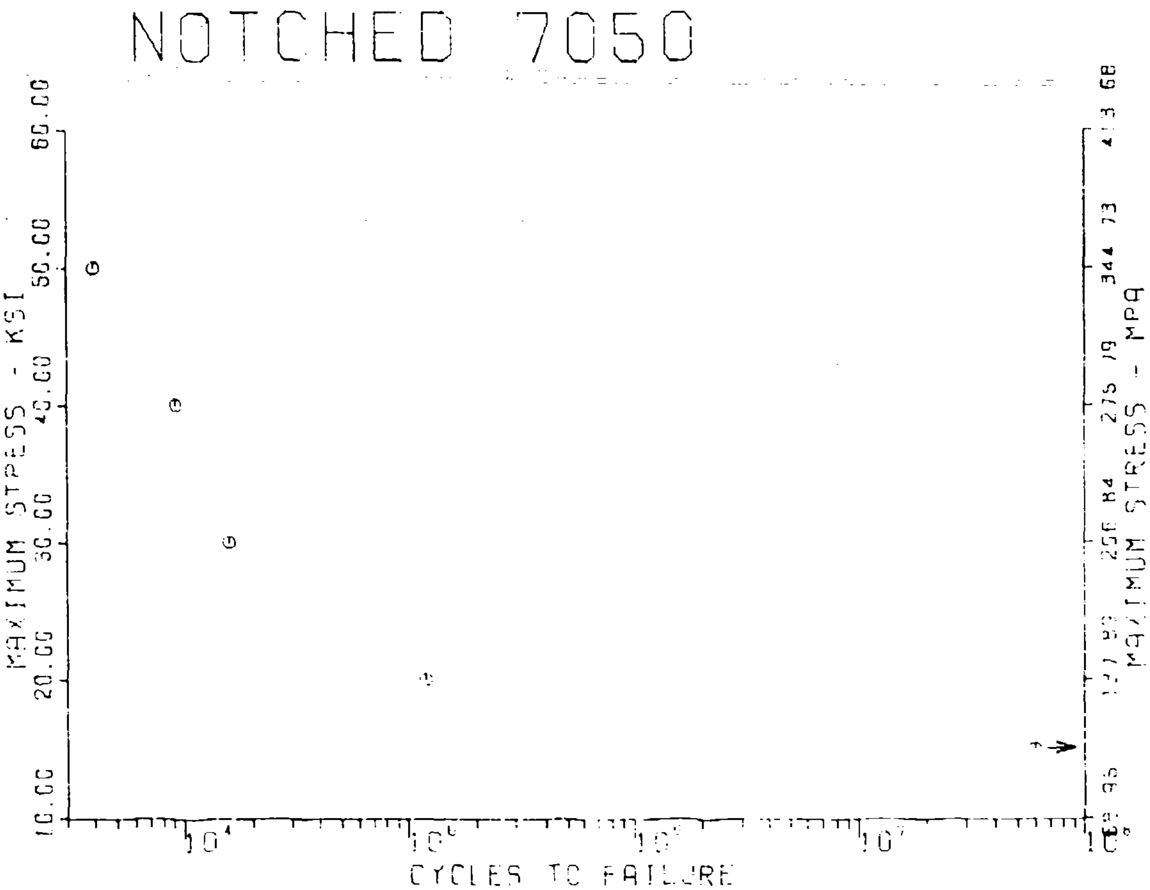


Figure 10. Notched Fatigue Test Results for 7050 Extrusions, Laboratory Air, R = 0.1, K_t = 3

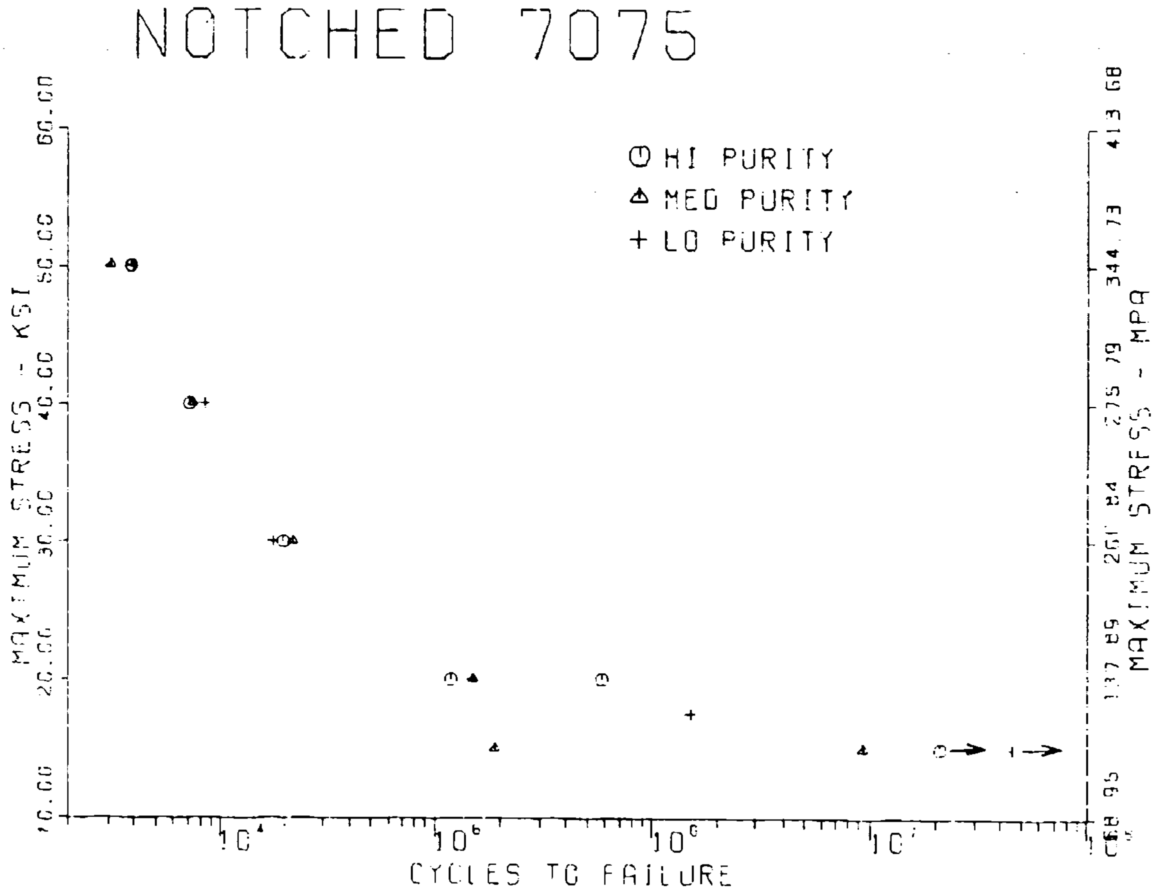


Figure 11. Notched Fatigue Test Results for 7075 Extrusions, Laboratory Air, $R = 0.1$, $K_t = 3$

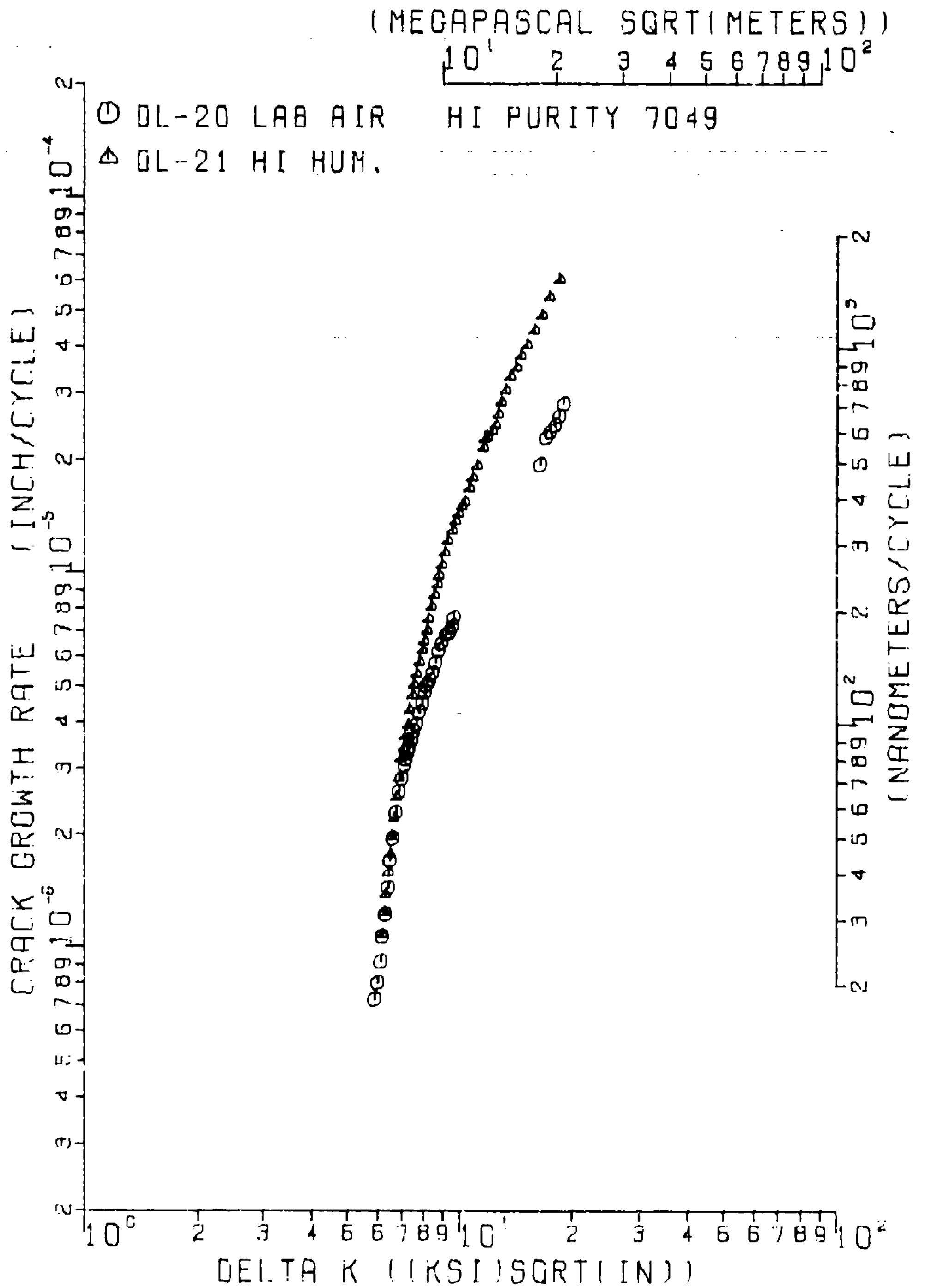


Figure 12. FCGR Data for High Purity 7049; R = 0.1, Freq. = 30Hz, L-T Orientation

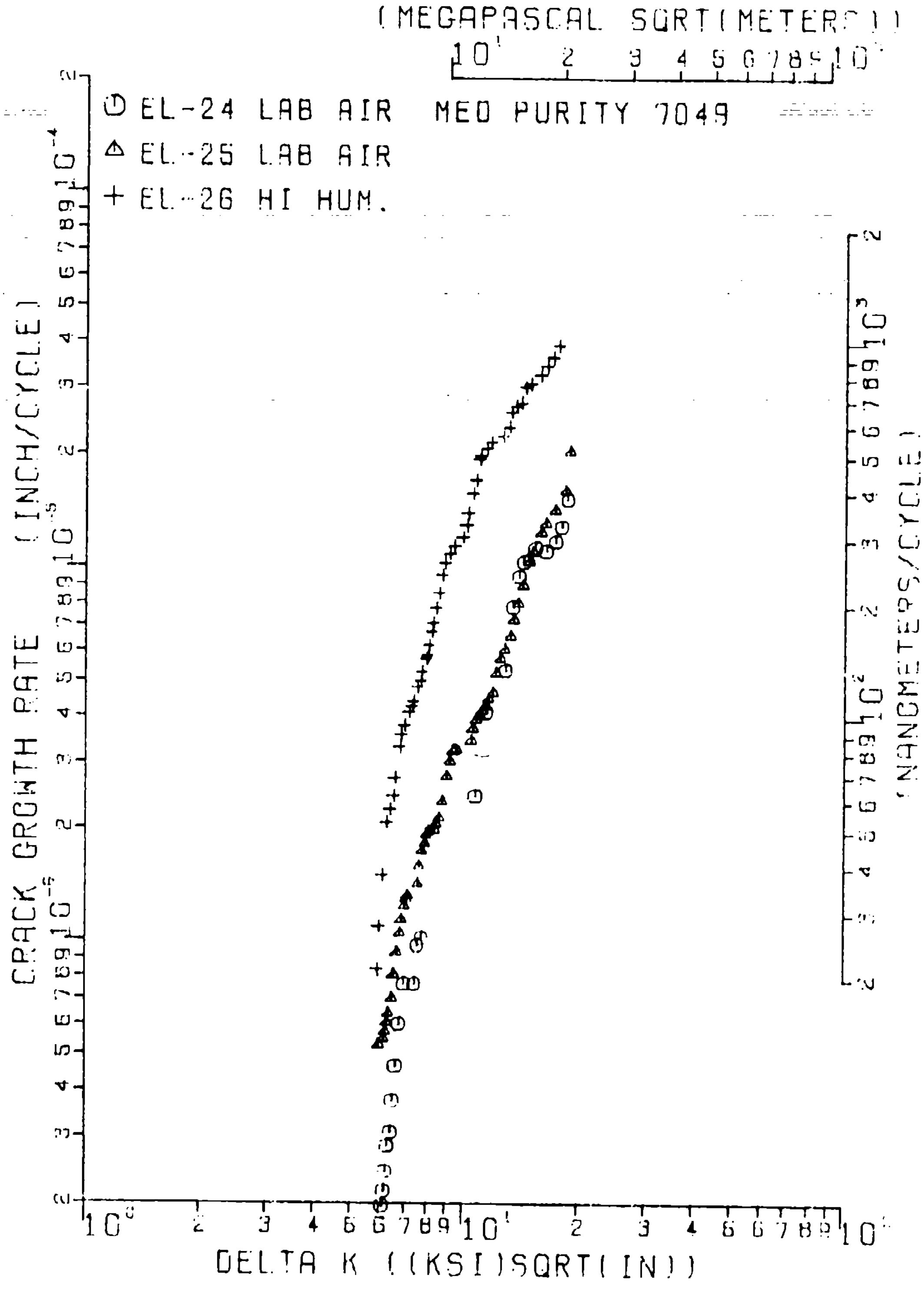


Figure 13. FCGR Data for Medium Purity 7049; R = 0.1, Freq. = 30Hz, L-T Orientation

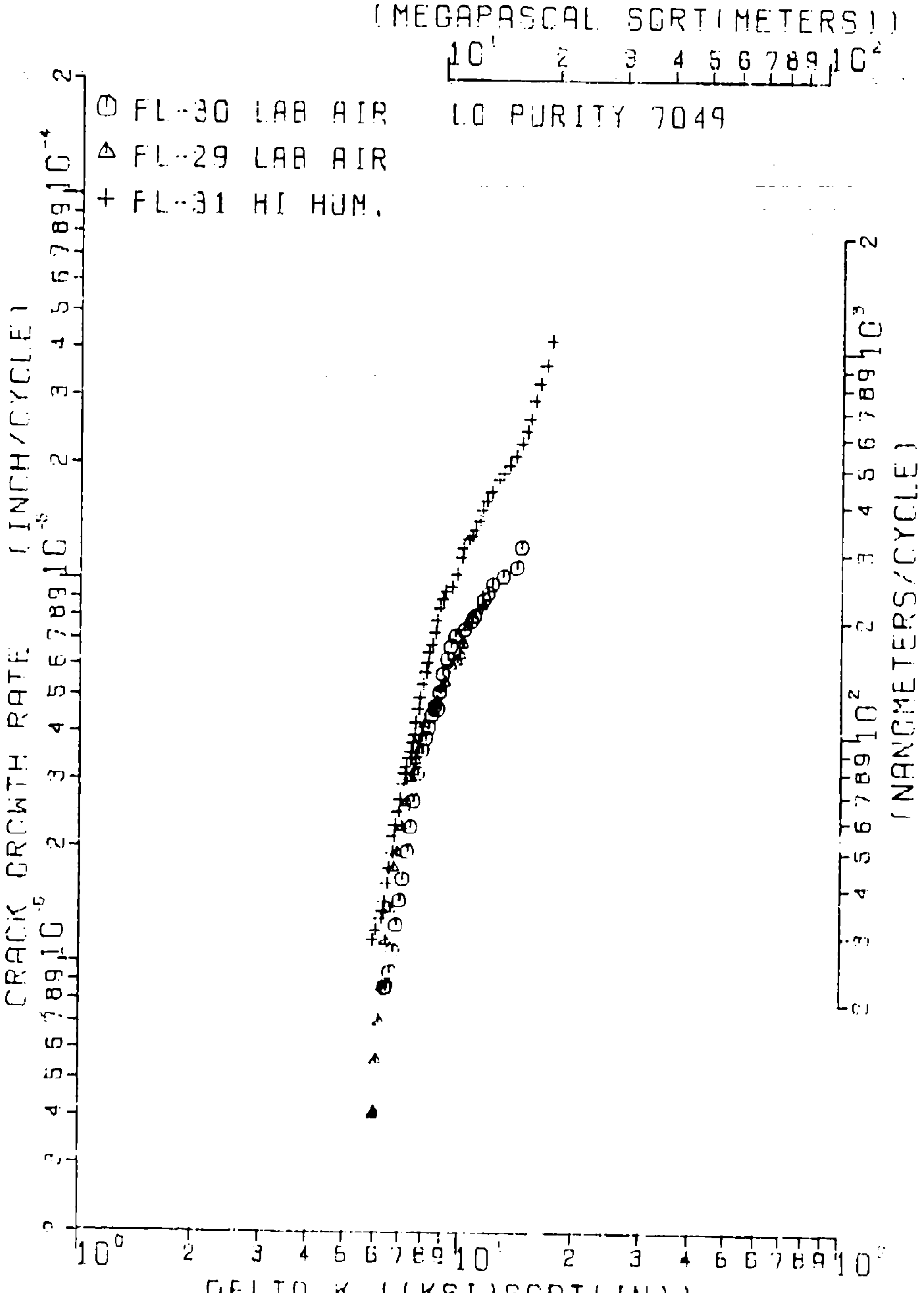


Figure 14. FCGR Data for Low Purity 7049; R=0.1 Freq.= 30Hz, L-T Orientation.

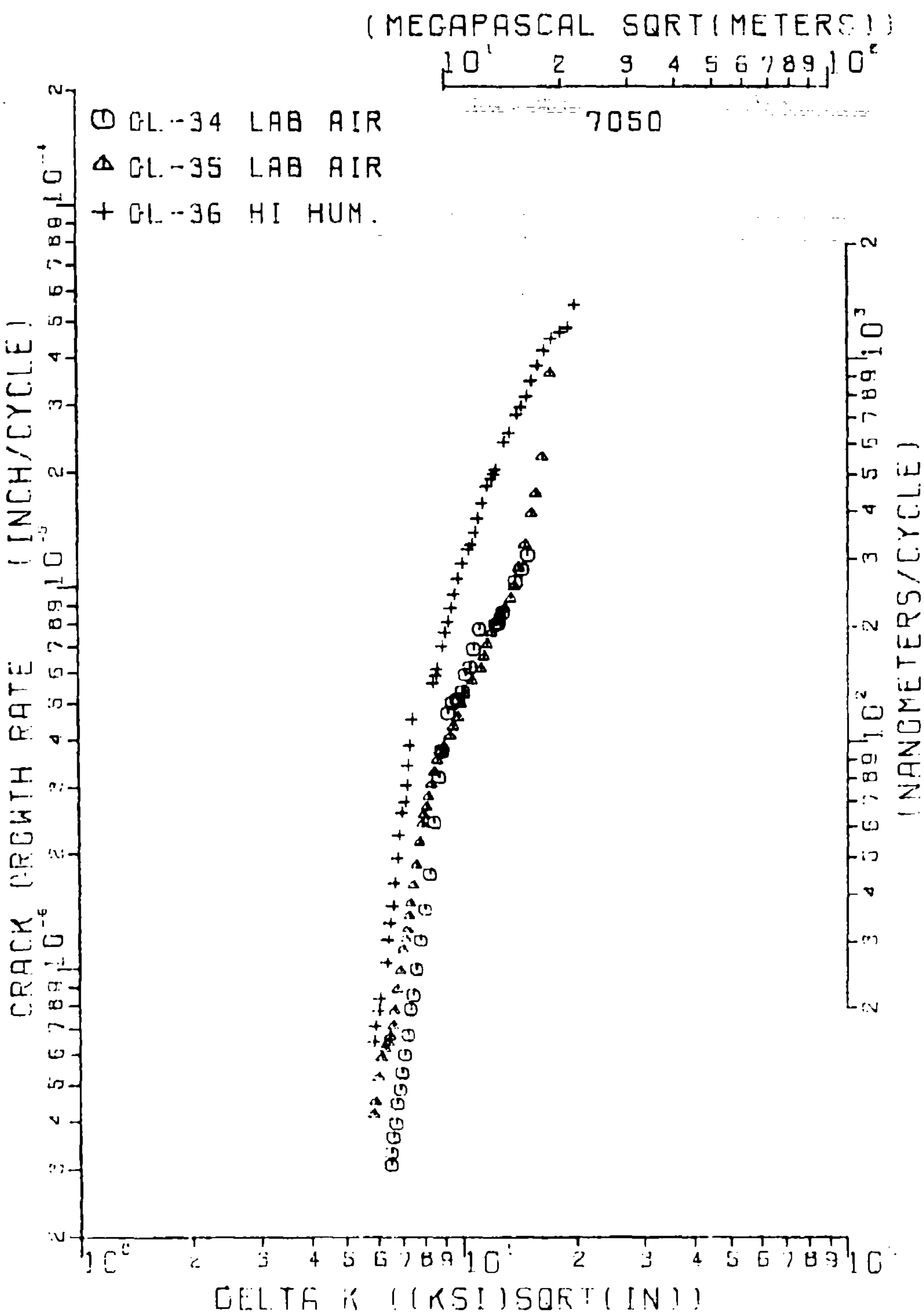


Figure 15. FCGR Data for 7050; R = 0.1, Freq. = 30Hz, L-T Orientation

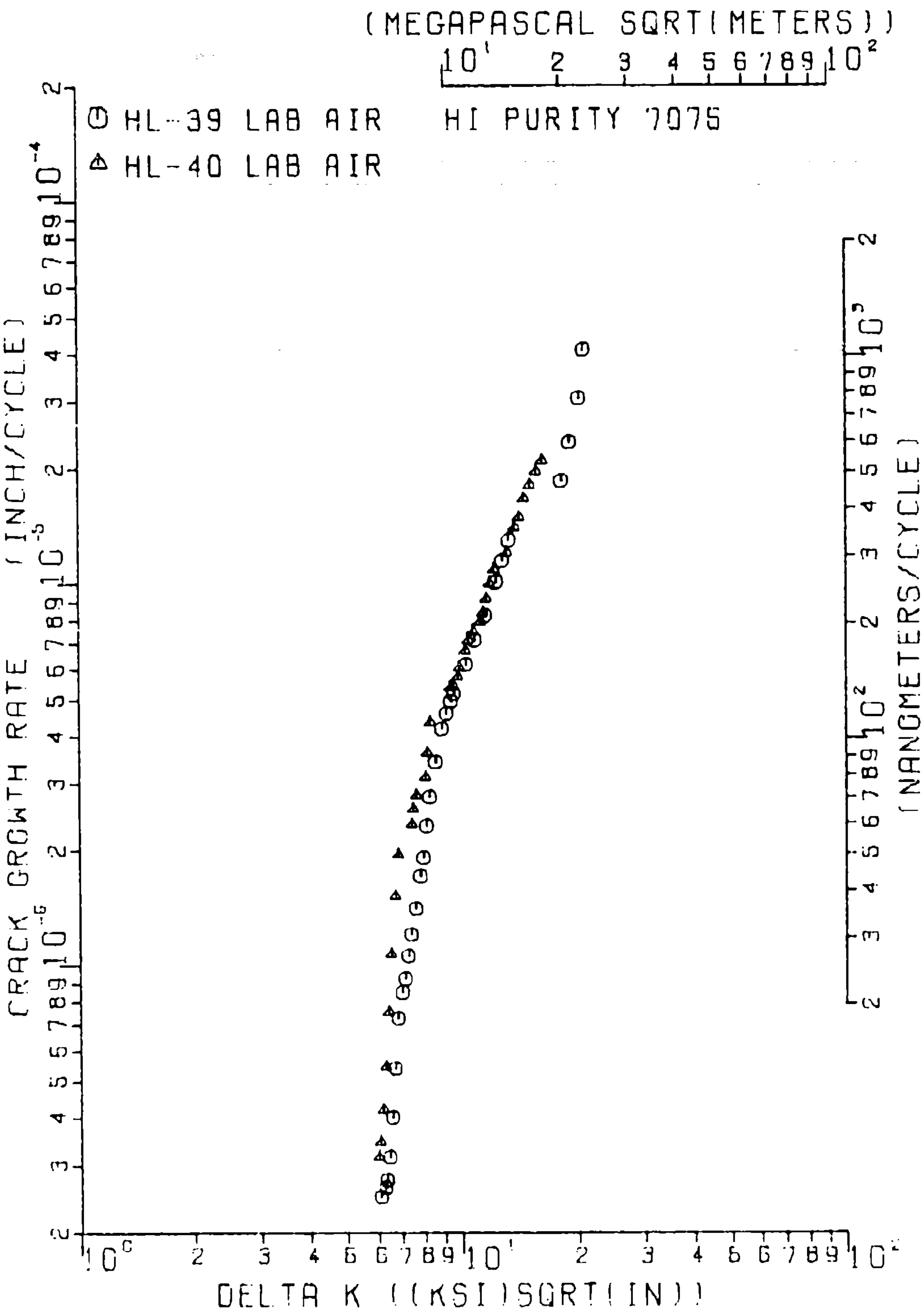


Figure 16. FCGR Data for High Purity 7075; R = 0.1, Freq. = 30Hz, L-T Orientation

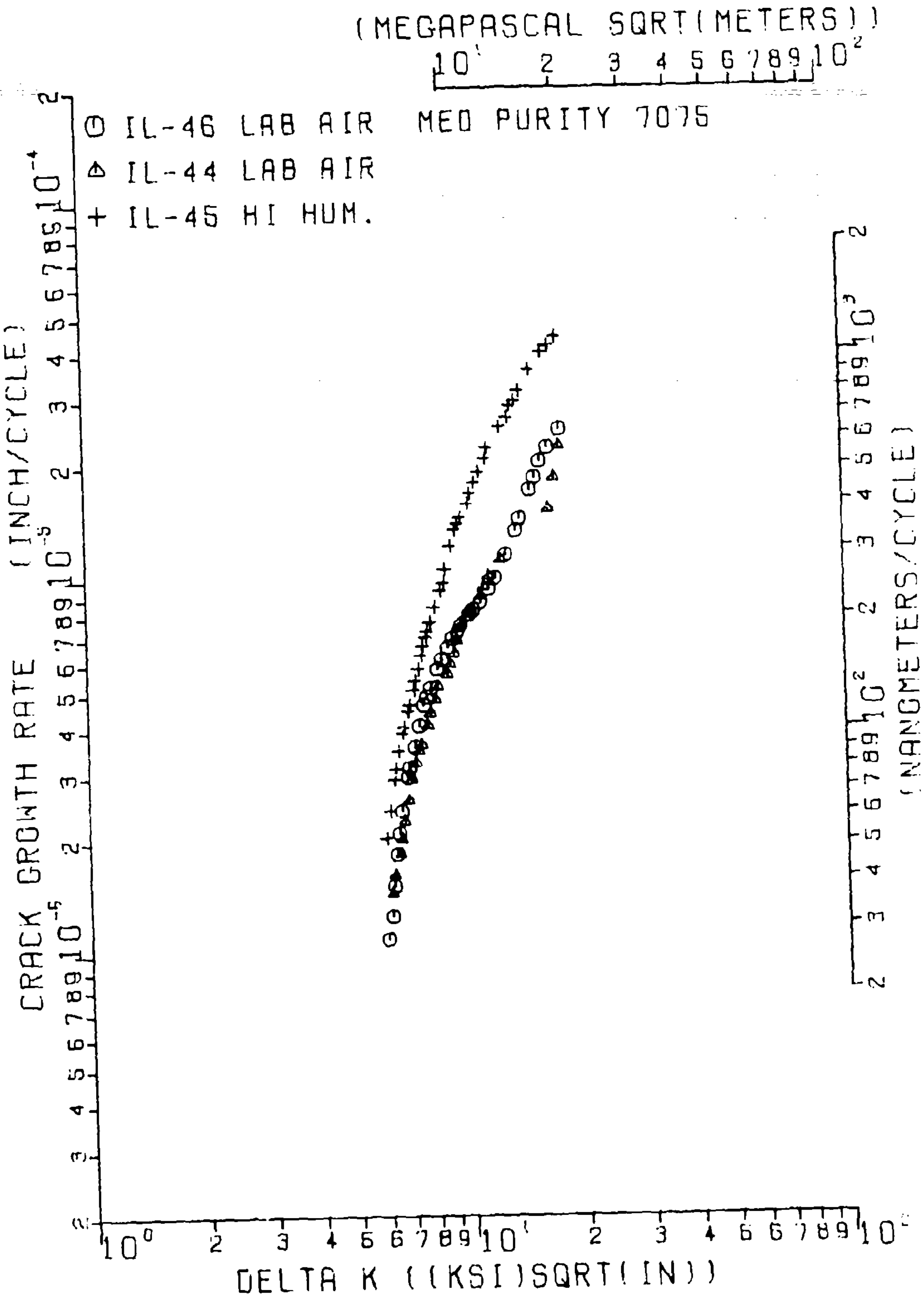


Figure 17. FCGR Data for Medium Purity 7075; R = 0.1, Freq. = 30Hz, L-T Orientation

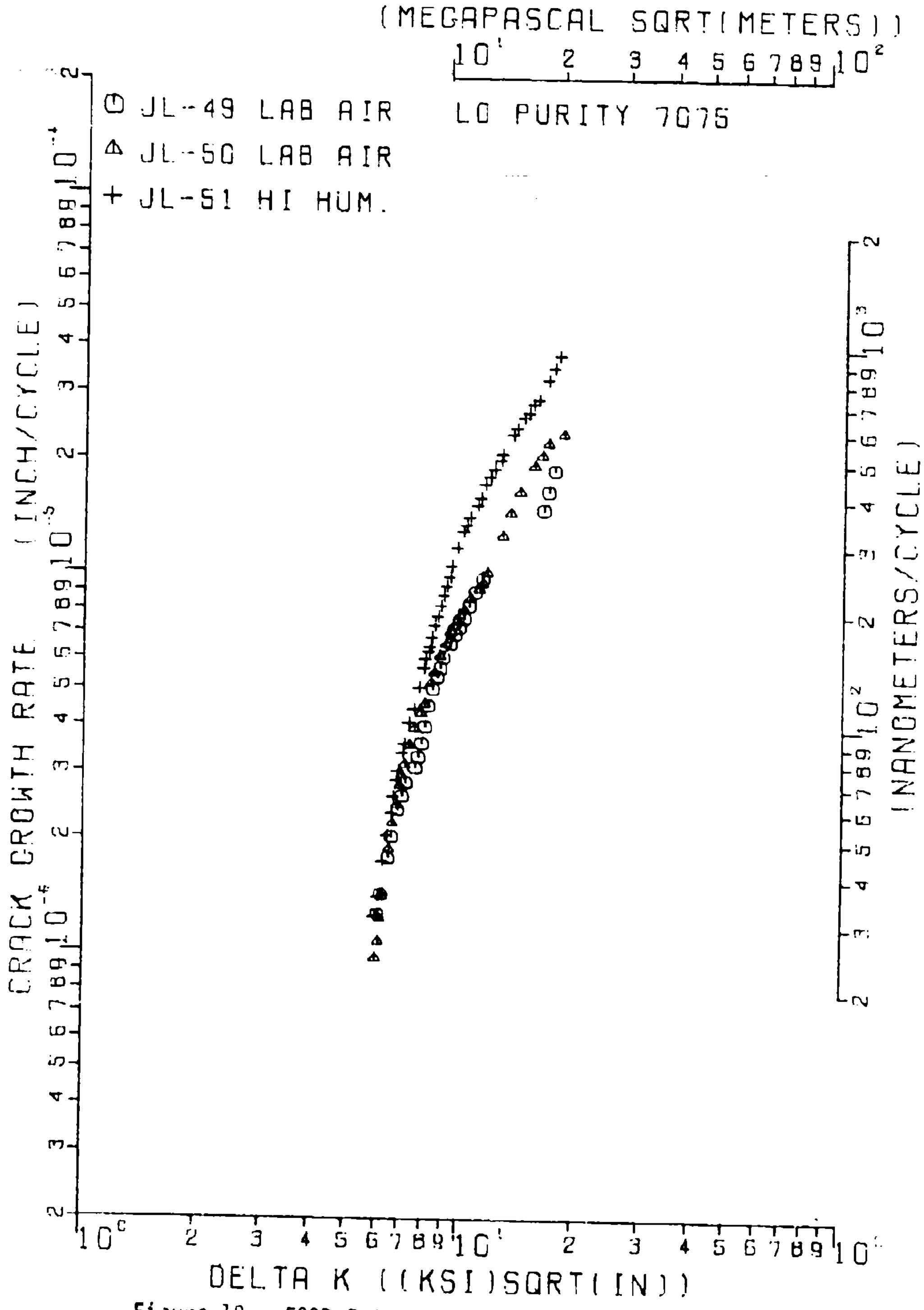


Figure 18. FCGP Data for Low Purity 7075; R = 0.1, Freq. = 30Hz, L-T Orientation

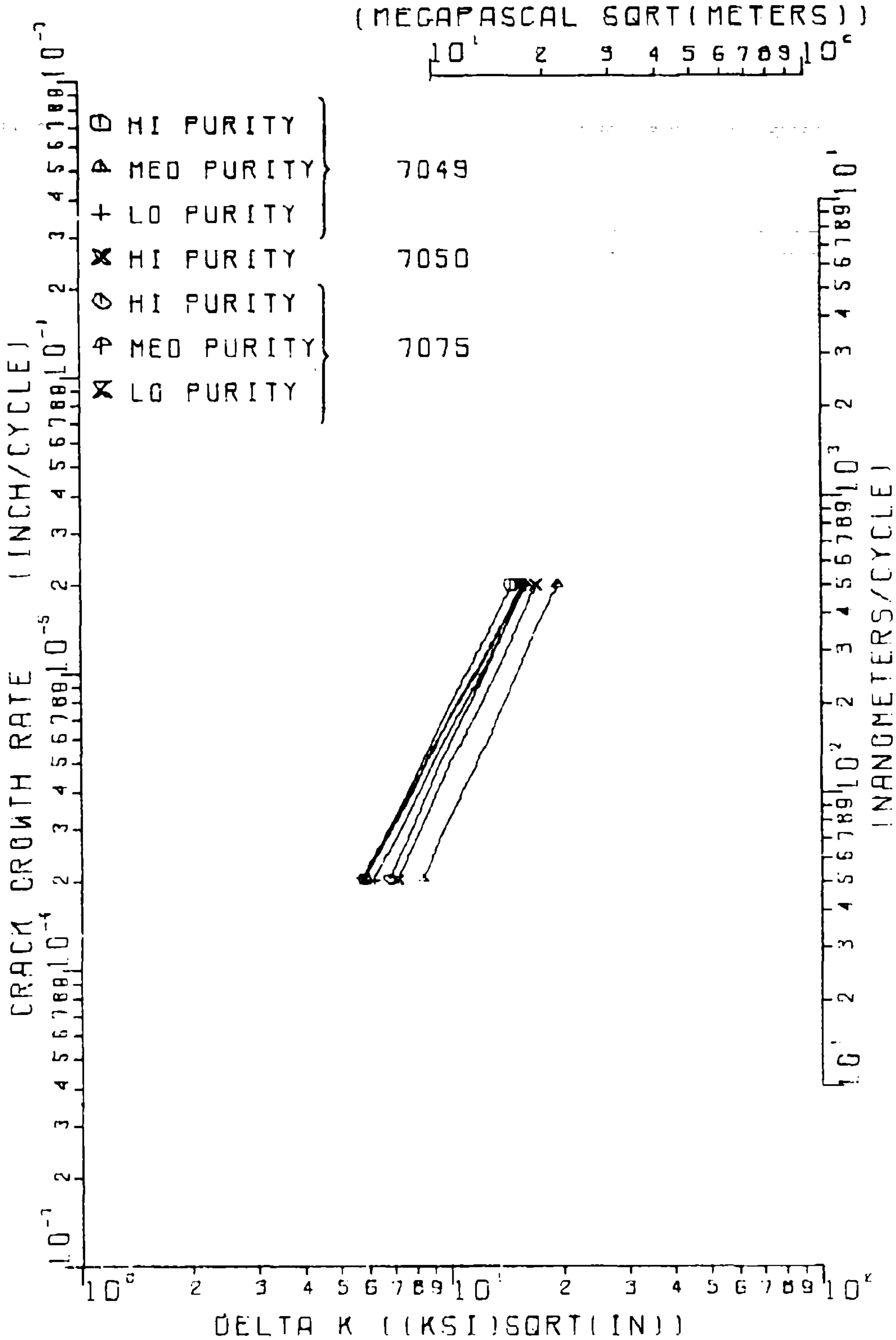


Figure 19. Comparison of Best-Fit Lines for L-T Orientation Specimens Tested in Laboratory Air

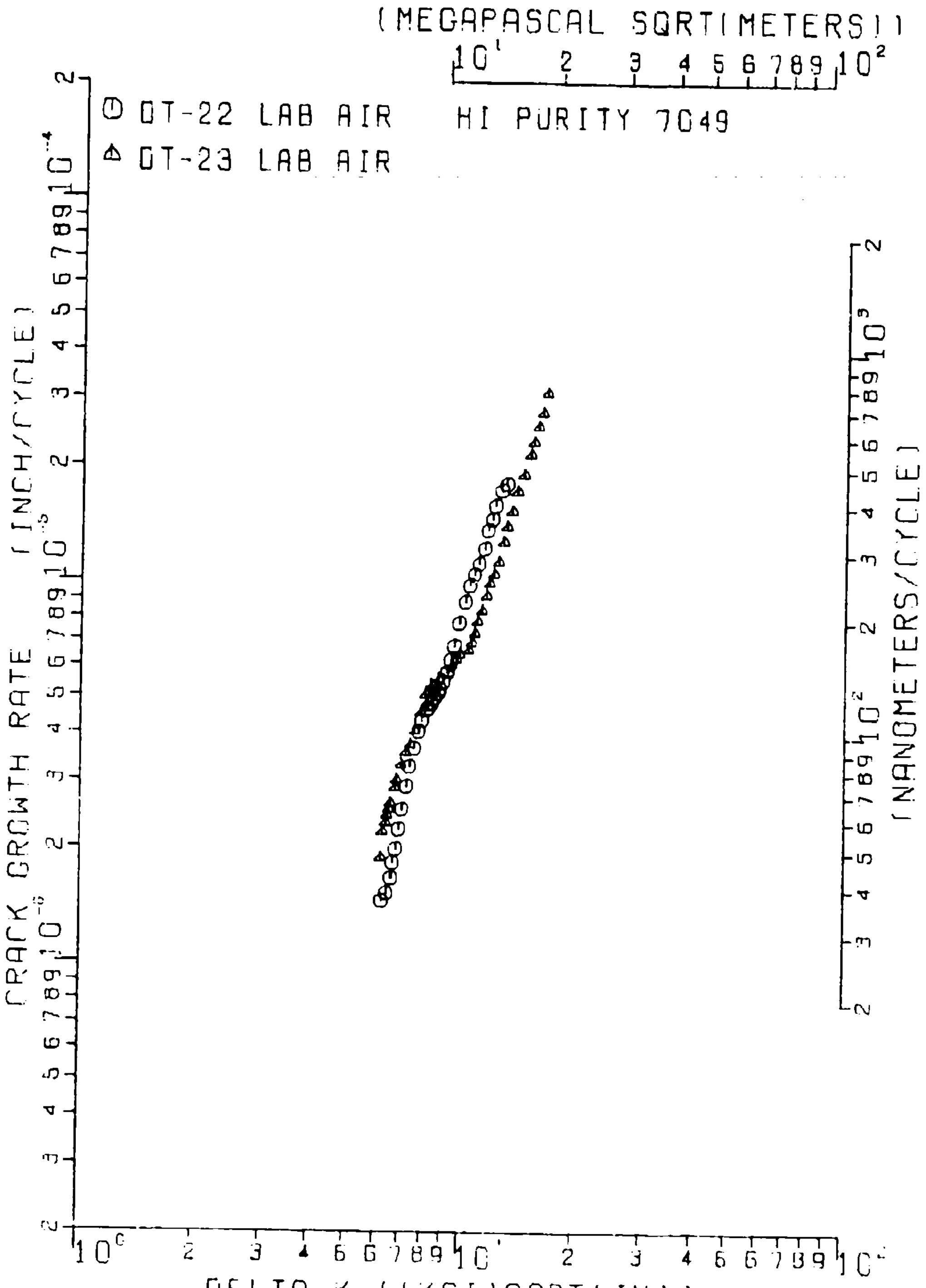


Figure 20. FCGR Data for High Purity 7049; R = 0.1, Freq. = 30Hz, T-L Orientation

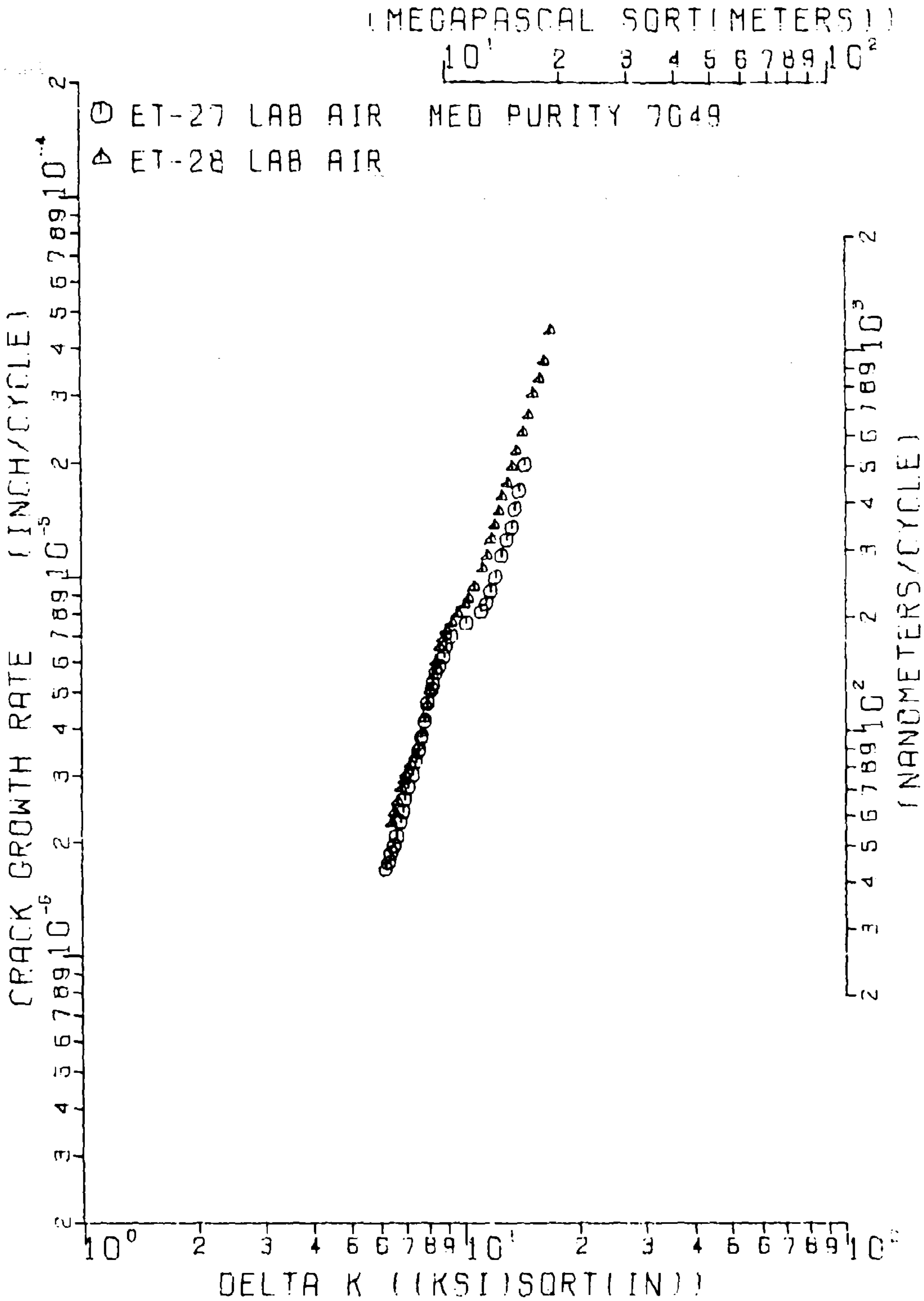


Figure 21. FCGR Data for Medium Purity 7049; R = 0.1, Freq. = 30Hz, T-L Orientation

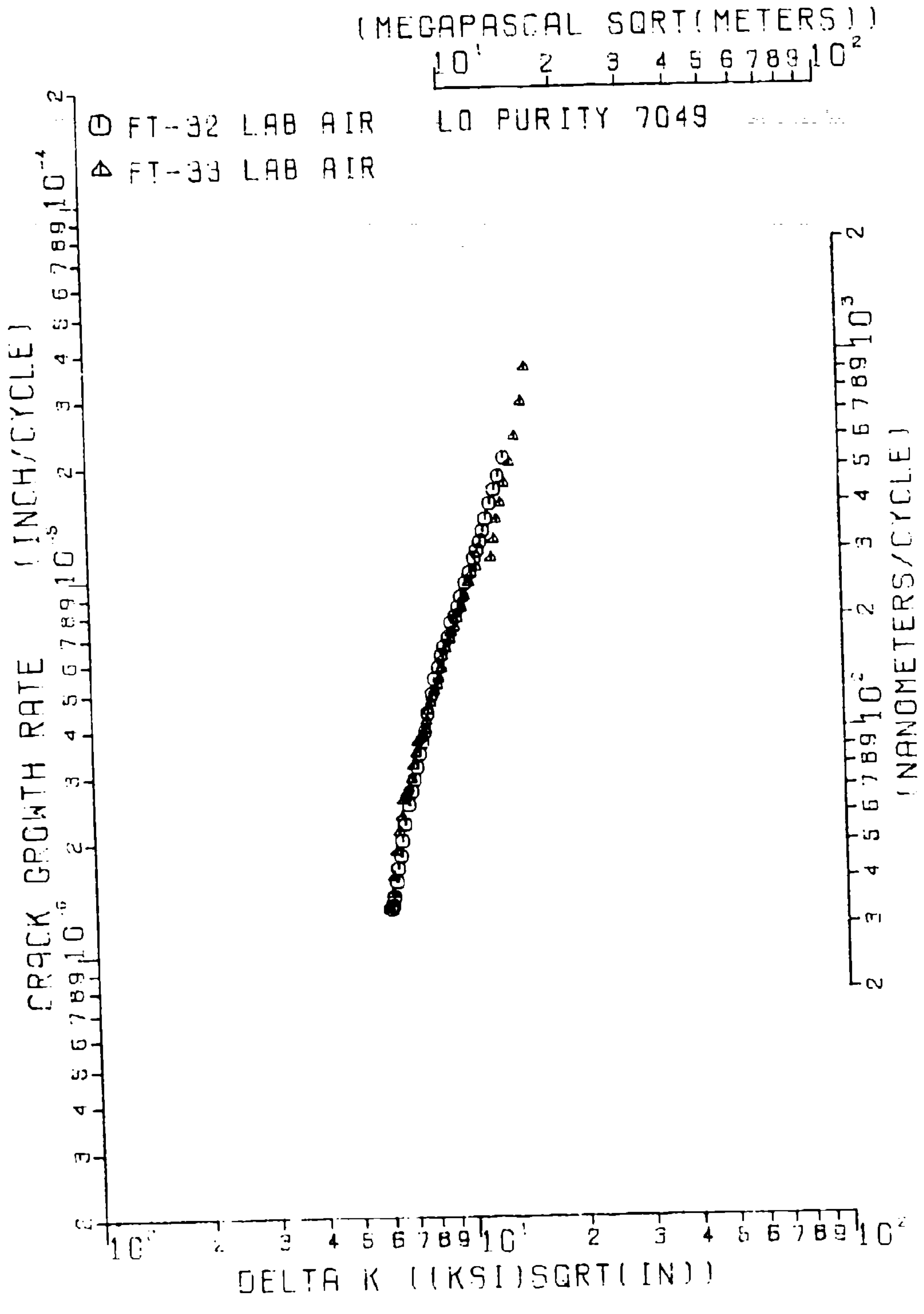


Figure 22. FCGR Data for Low Purity 7049; R = 0.1, Freq. = 30Hz, T-L Orientation

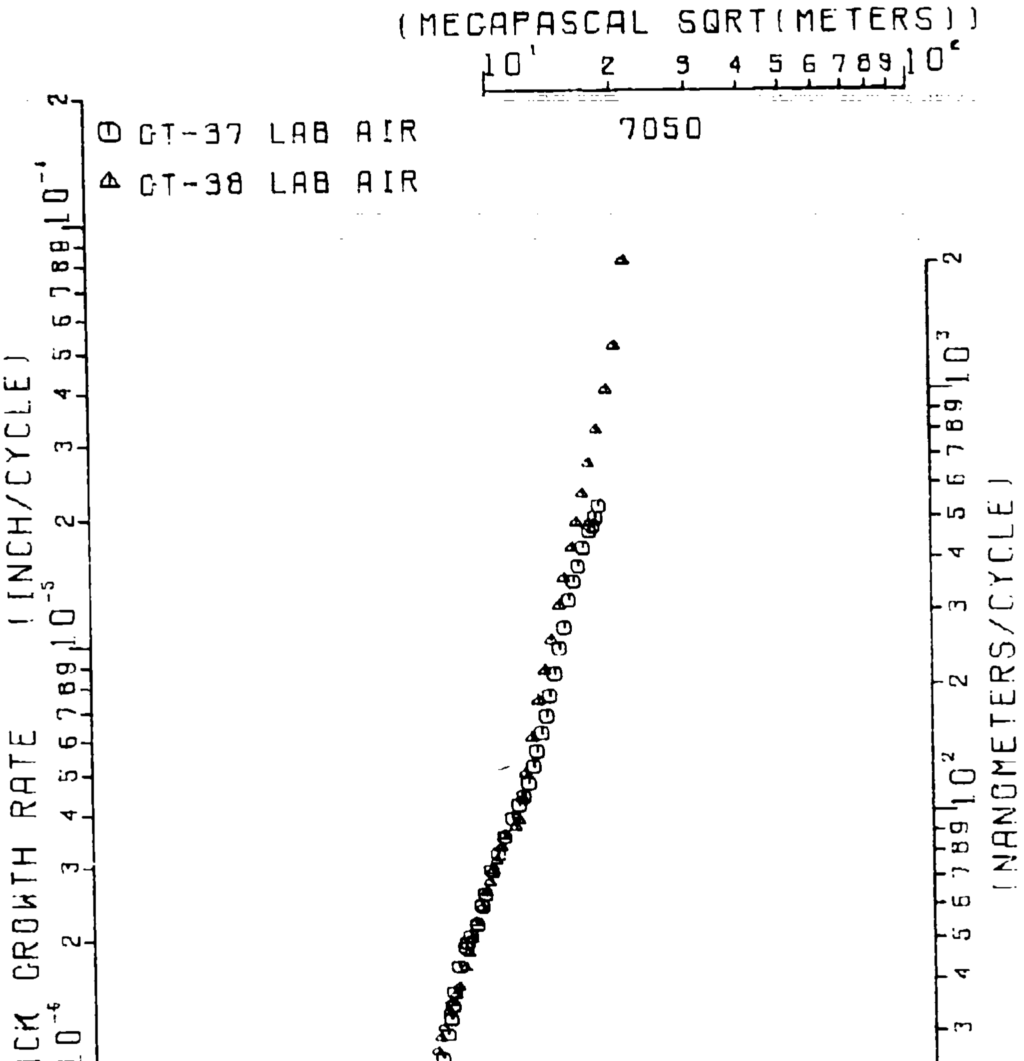


Figure 23. FCGP Data for 7050; R = 0.1, Freq. = 30Hz, T-L Orientation

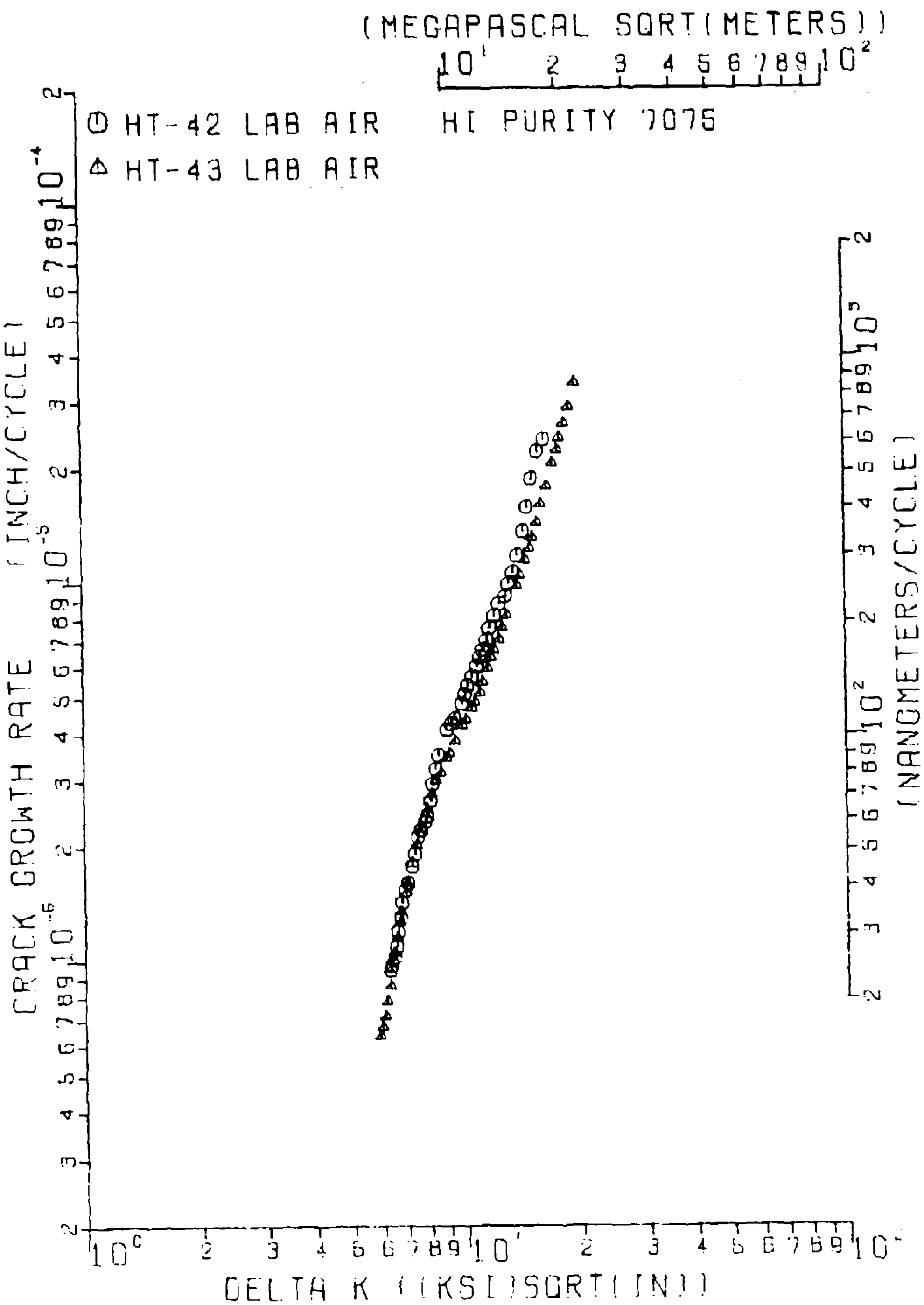


Figure 24. FCGR Data for High Purity 7075; R = 0.1, Freq. = 30Hz, T-L Orientation

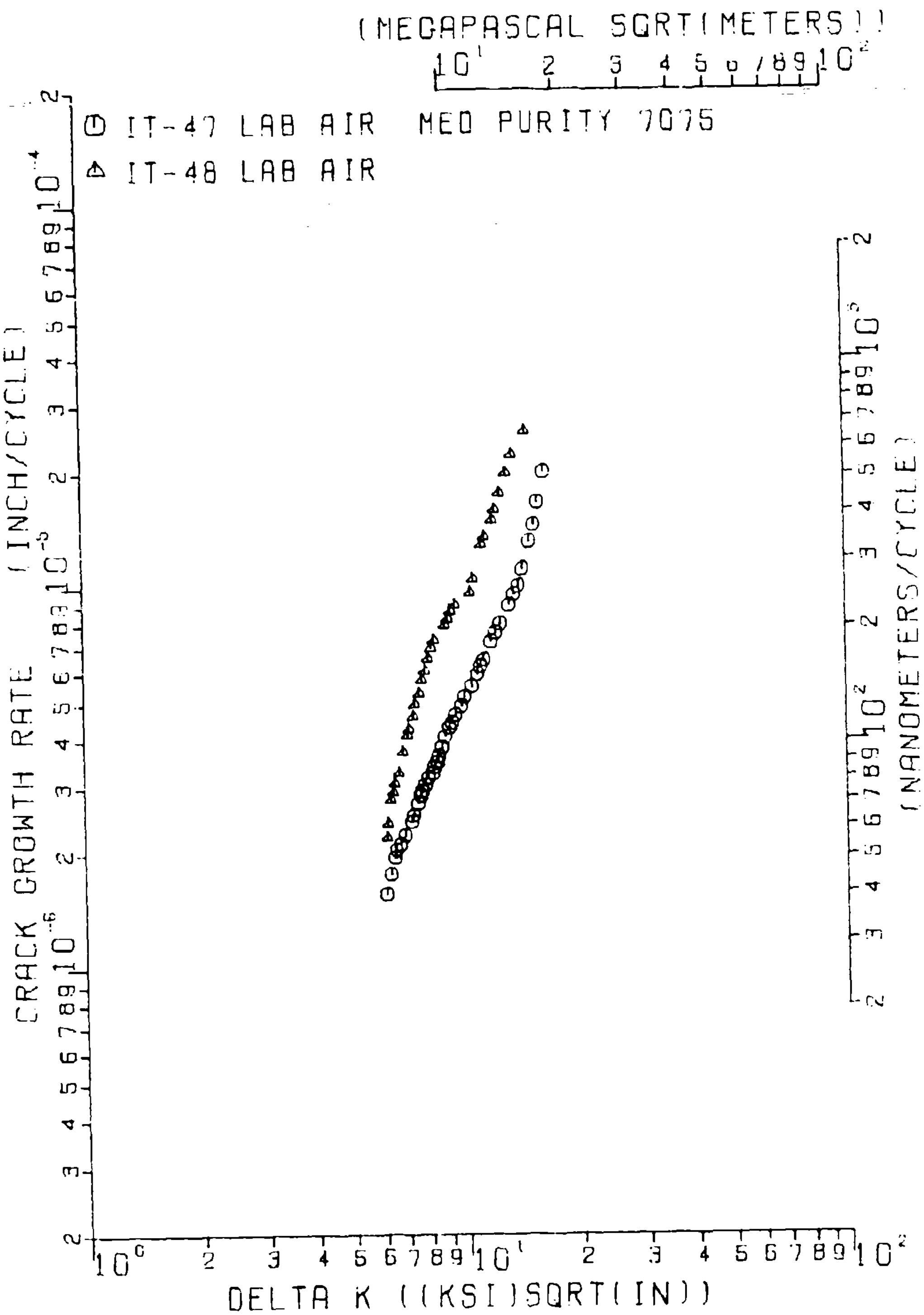


Figure 25. FCGR Data for Medium Purity 7075; R = 0.1, Freq. = 30Hz, T-L Orientation

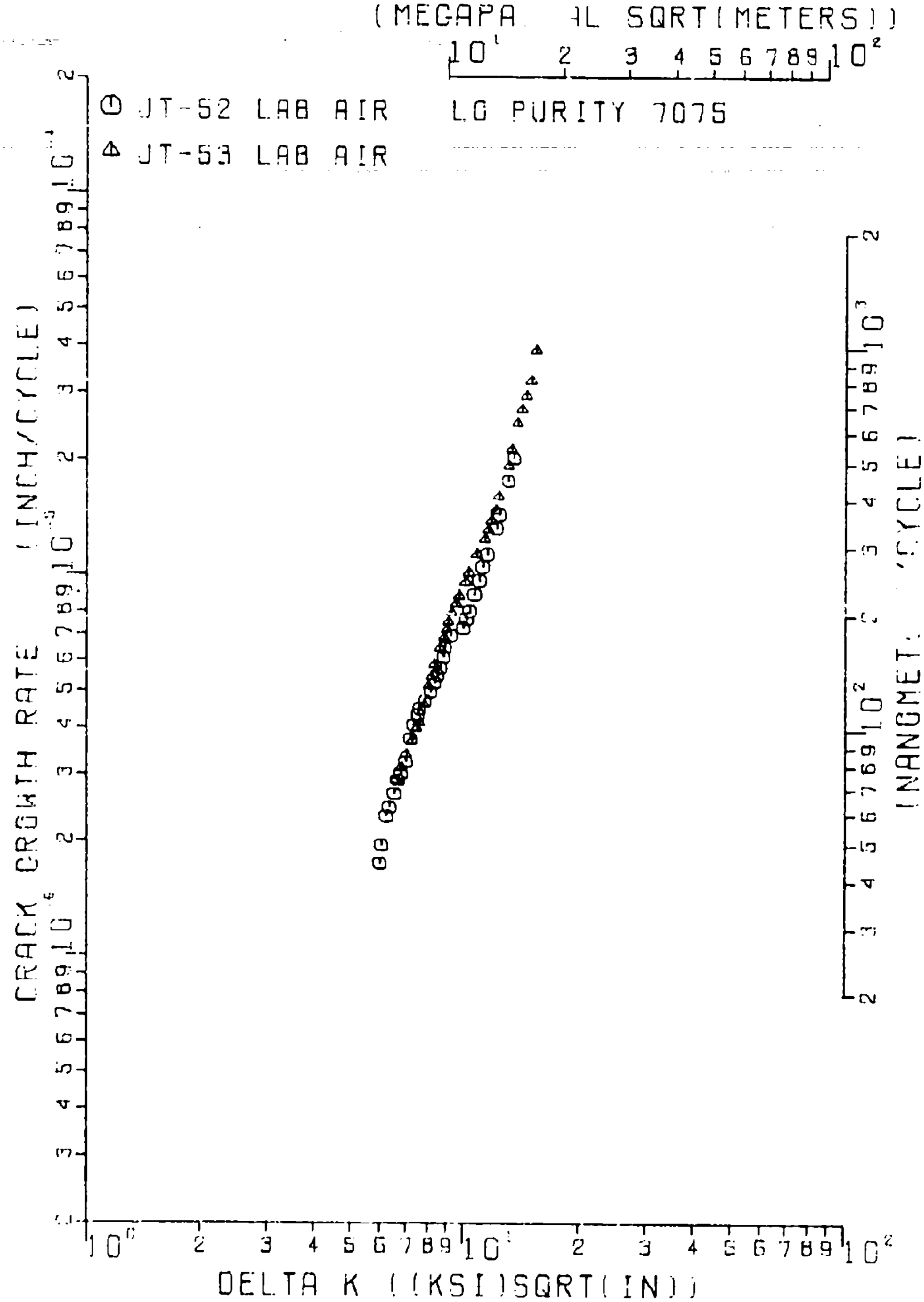


Figure 26. FCGR Data for Low Purity 7075; R = 0.1, Freq. = 30Hz, T-L Orientation

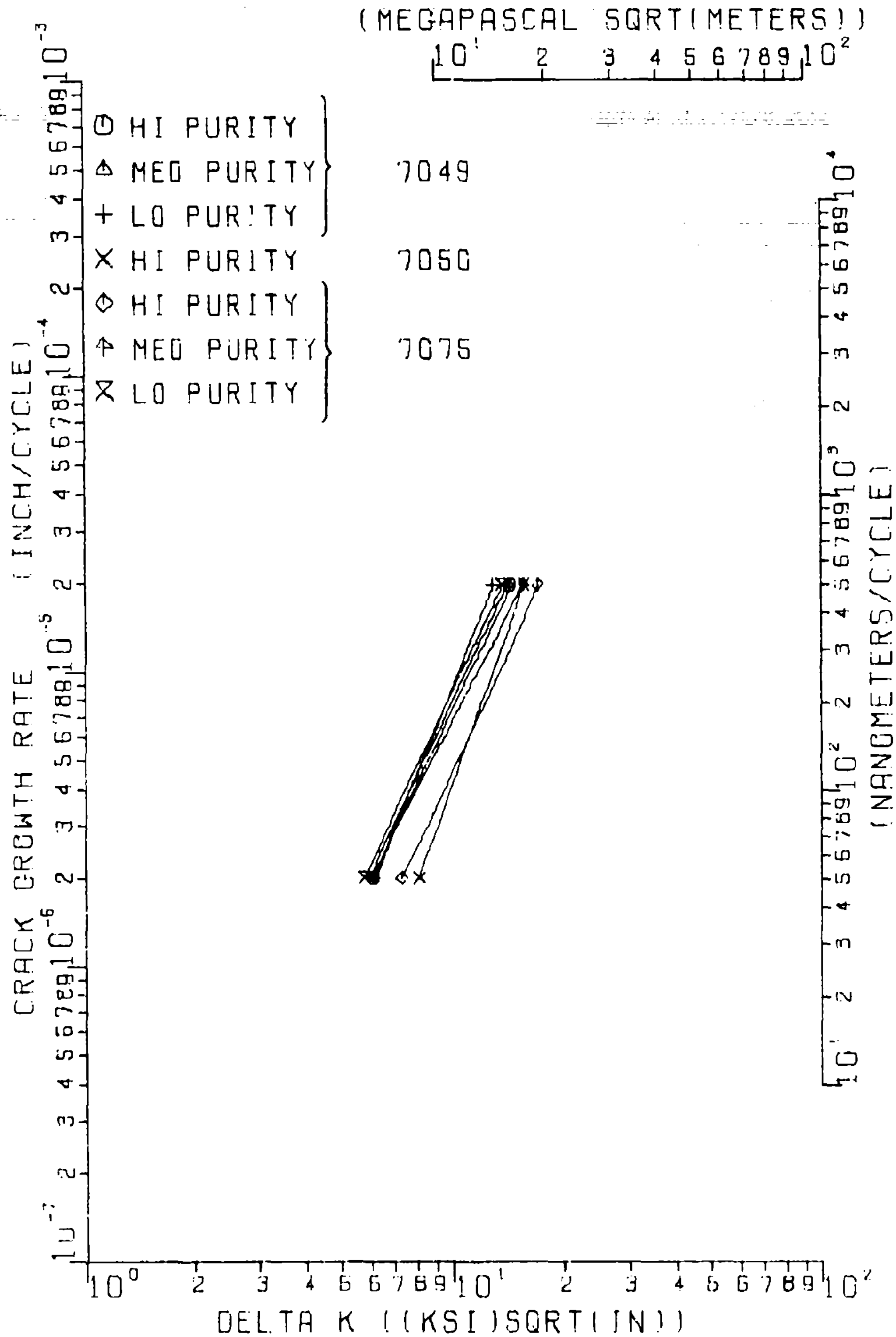


Figure 27. Comparison of Best-Fit Lines for T-L Orientation Specimens

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